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MANUAL OF METHODS IN FISHERIES BIOLOGY

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MANUAL OF METHODS IN FISHERIES BIOLOGY

compiled by

T. LAEVASTU

Fascicule 1

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FOOD AND AGRICULTURE ORGANIZATION OF THE UNITED NATIONS
ROME 1965

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FOREWORD

Several years ago, at one of the earliest sessions of the Indo-Pacific Fisheries Council, attention was drawn to the need for textbooks covering each of the aspects of fisheries science. Plans were then made for a series of manuals for the use of fishery workers in the Indo-Pacific region. Progress in preparing these was for several reasons very slow. In the meantime, the Food and Agriculture Organization of the United Nations had found through its Expanded Program of Technical Assistance, its experience in conducting regional training centers and, more recently, as Executing Agency of fisheries projects under the United Nations Special Fund, that the need for such manuals extended beyond the Indo-Pacific region. The Organization therefore undertook to sponsor the production of such a series for world-wide use. The present volume is the first of the series.

There can be no doubt about the need for manuals such as those planned. Fisheries science is new, its academic institutions few, and its practitioners far from numerous. It is natural therefore that few efforts should have been made to crystallize, in textbook language, ideas and concepts that are even now still taking shape. Nor does FAO wish to be premature in this matter, and these manuals will therefore not be textbooks in the usual sense, but rather practical guides describing techniques and plans and presenting such ideas and views on this science as at present have general currency. In doing this we have borne in mind that very frequently the original scientific publications in which methods are described may not all be available to the technicians and research workers for whom these manuals are intended, especially in developing countries: and also that although many of the methods for particular purposes – especially in oceanography – are more fully described in a number of existing manuals, these also are not always accessible, nor published in a language readly understood by the users.

An unusual feature of this and other manuals in the FAO series will be the combination of descriptions of methods for both inland and marine investigations: this, we believe, will prove especially useful in developing countries, where the very few trained people may be called upon from time to time to make *ad hoc* studies outside their own special competence.

The production of these manuals is a co-operative enterprise in which authors, consultants and users are joined together in deciding which concepts, methods and terms have survived sufficient testing to merit inclusion. Because fisheries science is growing rapidly, the manuals are issued in separate fascicules to allow for ready revision of individual sections.

The assistance of all fishery workers in the task of revision is sought, and comments and suggestions from readers would be welcomed.

Contributions to the first draft of a Manual on Field Methods were made over a period of years by several members of FAO Fisheries Division, Biology Branch, namely: W.C. Beckman, W.A. Dill, S.J. Holt, G.L. Kesteven (General Editor of this series) and T. Laevastu. This was issued in two mimeographed versions in January 1958 and September 1958, amendments to which were suggested by many specialists consulted. A printed provisional edition was distributed for comment early in 1960, to representatives of the Indo-Pacific Fisheries Council, to fisheries scientists in member countries of the International Commission for the Northwest Atlantic Fisheries and the International Council for the Exploration of the Sea, and to fisheries laboratories in most of the member countries of FAO. All the comments received were taken into account in revising the provisional edition; the correspondents who made detailed contributions or suggestions are too numerous for individual mention here, but their assistance was much appreciated.

The present volume also incorporates parts of a projected manual of laboratory methods of which a mimeographed version had been issued in 1958. This version of the combined manual was compiled by T. Laevastu who was at the time a member of the staff of FAO Fisheries Division.

Compilation and publication in three languages of a technical manual, such as this, is necessarily a lengthy process. Since work on it was begun the Inter-Governmental Oceanographic Commission under Unesco, and the Scientific Committee for Oceanic Research of the International Council of Scientific Unions have both come into existence, and the Unesco Office of Oceanography, the International Council for the Exploration of the Sea and other international bodies have, through specialized working groups and by other means, begun studies to review many oceanographic methods and to propose standards for them. It may well be, therefore, that several of the methods originally proposed for inclusion in this manual will soon be superseded: this may apply especially to parts of Section 2 and 3. Nevertheless, at the time of going to press the methods described are believed to be useful ones, even if some are not entirely satisfactory.

Work is in progress, too, in fields covered by other sections: for example, the nomenclature and classification of fishing gear dealt with in Section 5. As new or amended methods are described elsewhere, outlines of them will be

incorporated in revised fascicules of the relevant sections. Section 4, research on fish stocks, deals only with simple field observations. Other manuals in this series will cover in detail the collection and analysis of fish population data, and the statistical problems of sampling and experimental design, as well as the conduct of special kinds of field experiments, such as studies of fishing gear selectivity.

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Director, Fisheries Division

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MANUAL OF METHODS IN FISHERIES BIOLOGY

compiled by

T. LAEVASTU

Fascicule 2

Section 1. Planning, recording and reporting field work

FOOD AND AGRICULTURE ORGANIZATION OF THE UNITED NATIONS
ROME 1965

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SECTION 1. PLANNING, RECORDING AND REPORTING FIELD WORK

1.0 INTRODUCTION

The purpose of this manual is to guide those engaged in fisheries research in planning, carrying out, and recording their field work. It is intended primarily for beginners and junior workers, but, since it is a compendium of techniques, forms and tables, it may prove useful also to experienced workers.

The bulk of the book consists of description of techniques of observation and measurement to be carried out during expeditions. The techniques selected are those in most common use for their purpose, and each is described in detail sufficient to enable a worker to use it consistently and reliably.

An often overlooked aspect of this work is the importance of care in keeping records of operations. It is scarcely possible to give too much emphasis to the importance of recording each operation and its results as the work progresses; and these records must be made in a way to permit of effective and economic treatment of them later not only by the observer, but also by others. Much information is lost because sets of data or material are ambiguously identified and because the circumstances under which they have been obtained are incompletely recorded.

1.0.1 Selection and standardization of techniques

In designing or choosing a technique, thought must be given to the following elements:

a purpose for the measurement or observation (that is, a use for the data to be obtained);

which particular physical property to measure or observe;

which equipment is most suitable for the measurement or observation in question, with special regard to the precision obtainable with them;

the manner of manipulation of the equipment in taking the measurement;

the units and forms for recording the measurements and/or observations;

the place, time and frequency of the measurements and/or observations;

the cost per measurement, in time or in money, in relation to the expected results.

Let us treat an example in this way and take length measurement of fish for this purpose.

The purpose of measuring the length of fish in fisheries biology is to ascertain the length composition of the stocks being studied and, by manipulation of the data, the growth rate and other characteristics of these stocks. Continuation of such operations, accompanied by environmental studies permit the research worker to ascertain the influence of the environment on these characteristics and their response to changes in environmental influences.

The physical property to be measured may be the total length of the fish, its standard length, or some other dimension that will reliably represent the size of each fish. The choice of dimension is subject to a number of considerations. Between a number of over-all lengths we must judge which permits the most accurate and consistent results with greatest ease and speed; total length might be easier to measure than length to caudal fork, or than length to caudal base, but for a particular species it might be that measurement of total length (that is, from snout tip to tip of tail at greatest extension) might be unreliable because of frequent damage to tail tip, or might be slow because of the difficulty of getting consistent extension of the caudal fluke.

The shape of the fish might make measurement difficult. It may be, in some species, that a difference between the rate of growth along a normal axis and that along other dimensions might make measurement along the normal axis less informative than measurement along another. Again, the fish may have been partially butchered, so that measurement of total length is not possible; in such cases resort may be made to measurement of some partial dimension and the relation of the chosen dimension with total length should be ascertained.

By this time the main characteristics of the equipment will have been fixed by the choice of the measurement to be made, but further decisions must be made as to the total units in which to measure and the precision to be obtained. A choice must be made between metric or other system of units.

The circumstances under which fish are to be measured may play a considerable part in determining what can be attempted. On the deck of a fishing vessel and on market floors, the need to get the fish quickly stowed away or dispatched to buyers is generally so great that only the simplest operations can be undertaken. Often, in such cases, the measurer will take only length measurements from as large a sample as time permits (subject to sampling rules), and will take a subsample, of fewer fish, on which to make more detailed measurements. In these cases simpler techniques of measurement may be used; for example, the length may be recorded simply as holes in a celluloid strip. When such simple equipment is used the identity of individual measurements is lost at once and the result is simply, and immediately, a length-frequency tabulation; this contrasts with the result of more

detailed measuring, where each fish is represented by the results of various measurements and observations, say of total length, body proportions, sex, gonad condition, stomach contents, and so forth. Of course, where such other measurements are made, the purposes of the work are broader than those stated at the beginning of this exercise.

It is worthwhile to consider what standardization means in this work. Choice must be made of equipment, manipulations and degree of precision, and it is here that the major part of standardization is effected. Statistical methods can be used in comparing results obtained from the use of different types of equipment and different sets of manipulation; these comparisons may be referred to the desired degree of precision. These statistical tests will evaluate each item of equipment and each method.

By standardizing in this way we should be able to ensure that if a particular instance of a particular physical property were to be measured by a group of workers their results would differ only by unavoidable error; and that all data from several separate research programs measuring a particular physical property could be treated as though they were the result of the work of a single person or team. However, the differing circumstances under which research in fisheries biology must be carried out demand relaxation of the more strict rules of a standard. Nevertheless, if a standard has been agreed upon for any procedure, departures from the standard should be clearly shown in accounts of the use of the procedure.

1.1 PLANNING OF RESEARCH AND EXPEDITIONS

Much of the success of an expedition depends upon careful planning before the field work starts. Such planning saves time and money, and ensures that no essential measurements and observations are overlooked. Usually there should be a precruise conference with the staff, after which the final plans are made by the field-party chief, or the scientist in charge.

Whether planning field trips or cruises, the following points should be borne in mind:

1. *The objectives.* To establish these it is necessary to know:

(*a*) What information is required and how it is to be applied. For example, whether it is purely scientific, to widen knowledge, or is for the improvement of some specific aspects of the fisheries industry.

(*b*) How to obtain information in the easiest and most reliable way, and therefore what observations or measurements must be made, and which are the other factors and elements related to the investigation.

(*c*) How the results are to be presented.

2. *Prior information.* All previous information on the special matter under investigation should be studied. If there is none available, the investi-

gator should familiarize himself with the information dealing with closely related subjects or areas. Furthermore, it should be ascertained whether there are data on observations or material in the laboratory or at the base, which have not been worked on, and if this material is complete or not. By doing all this, duplication of previous work is avoided and the investigator profits from past experiences.

3. *The time and money available* for the trip and for studying the collected data. Only such data or material should be collected as are necessary to solve specific problems and can be worked on in a reasonable time in the laboratory or base. The efficiency and experience of observers must also be considered, especially when choosing the personnel.

4. *Choice of instruments.* This depends on what is available and on the investigations that have to be conducted. This matter is discussed in greater detail in the following subsections. The handling of instruments is described in Sections 2 to 5.

1.1.1 Types of operations

The operations in fisheries can be grouped by their purpose as follows:

1. *Reconnaissance.* General study of an area to obtain a picture of its main characteristics.

2. *Exploratory fishing.* Use of various types of fish-searching equipment and fishing gear to ascertain the kinds of fish present in an area and to obtain some idea of the magnitude of the stocks of these. Information would also be obtained on such things as nature of bottom, and sea conditions, that might affect fishing.

3. *Prospecting.* Use, in a particular area, of fish-searching equipment and fishing gear appropriate to one or more species known to be present in the area, to obtain a detailed picture of the distribution of these species and estimates of the magnitude of the stocks.

4. *Experimental fishing.* Use of fishing gear to determine the properties of the gear itself, or of the entire unit of which the gear is part, especially with regard to its effect on the fish stocks. Comparative fishing experiments are probably the most well-known examples of such operations. Experiments to determine the gear most useful in a particular area, or for a particular species or group of species, are included here.

5. "*Census*" *and routine operations.* Regular field work, in markets, at landing places and on fishing grounds, in sampling fish catches and stocks, to ascertain certain characteristics of the populations under exploitation, such as age, size and sex composition, growth rate, reproduction and recruitment, and mortality.

6. *Analytical operations.* Bioanalytical work such as tagging, special sampling of noncommercial stocks (eggs, larvae, young fish, fish food), and research in fundamental biology (e.g. behavior and physiology), to ascertain characteristics of the stocks and their environment not revealed by any of the preceding operations or by analysis of data on commercial fishing operations.

It will be observed that in the above list each type of operation is defined in terms of objectives and equipment. The foregoing are primary operations for fisheries biology; each is generally accompanied by complementary operations, that is, work in meteorology, oceanography or limnology.

Commercial fishing operations as such are included in the above list only in category 5 where the research operation draws its material by sampling of commercial catches.

It must be kept in mind that in looking at the work in this way we are not suggesting that the complementary operations are of less value or importance than the primary. In fact, the complementary operations of the programs with which this book deals are the entire operations of other programs. However, in this program, the specification of the environment is secondary to the work directly on the fish stocks, even if a specification of some degree is essential to most fishery research.

For an institute engaged equally, or almost equally, in fisheries research and in "pure" oceanography or limnology, it presumably is necessary to decide which type of program on each occasion will have prior claim on the operational plan of the expedition. If fisheries have prior claim, the plan would be developed as described here, with the oceanographic or limnological work carried out either solely as complementary operations, or as complementary operations with additional work as opportunity permitted. If oceanography or limnology have priority, then fisheries work would be carried out as opportunity offered. Any conflict between technological research and research in fisheries biology would be similarly resolved.

1.1.2 Operational plan

An operational plan is a statement of: (1) operations to be performed and techniques to be used; (2) itinerary to be followed and stations to be occupied; (3) operational routine to be followed at each station.

There are two main types of field expeditions, each needing different planning:

1. (*a*) Trips on shore; (*b*) in small boats, close to the shore and of less than 24 hours duration; (*c*) observations on commercial fishing vessels. Trips of this sort are usually made by one or two men.

2. Cruises in research vessels of more than 24 hours duration.

1.1.2.1 Trips on shore

Shore trips are usually made for the following purposes:

(*a*) Reconnaissance survey of fisheries conditions (catch, gear, economics) in various villages and harbors and for interviewing fishermen. (*b*) Sampling and/or inspecting of commercial catch. (*c*) Investigation of beaches for various purposes.

The points to observe when planning for this kind of trip are:

(*a*) Transportation.

(*b*) Equipment. This depends on the kind of work to be done and on the means of transportation. Most laboratories usually have specially designed transportable field kits for trips on shore and in small boats. A fisheries biologist should always carry with him on such trips the following simple equipment:

1 pocket set of dissecting instruments
1 tape measure (meter)
1 magnifying glass
1 diary and pencils
1 pocket spring balance
1 sea chart of the area
1 small portable thermometer
1 camera

1.1.2.2 Trips in small boats close to the shore

The planning of these trips again depends on factors peculiar to the locality and laboratory and on the type of work to be done and the information to be collected. Usually trips of this sort are made from the laboratory or fishing harbor as the base, for the following purposes:

1. Collection of animals or water samples for laboratory studies.
2. To test instruments.
3. Local plankton and benthos studies (e.g., investigation of seasonal variations).
4. Local station hydrographic studies, such as tides and sea water sampling.
5. Coastal pollution studies.
6. Experiments with small fishing gear, such as long lines, trolls, gill nets, traps, beach seines.

The planning also depends on the size and seaworthiness of the boat, and

on the duration and distance from the shore. The following should be considered:

1. Weather situation and forecast.

2. The instruments suitable for use, and methods to secure them in small boats.

Small diary logs are generally used on these trips. However, if fishing and plankton work is to be done, the general fishing log and the plankton log should be used (see Section 1.2).

1.1.2.3 Observations on commercial fishing vessels

Observations made on commercial fishing vessels are usually to:

1. Sample the commercial catch.

2. Observe the behavior of gear.

3. Make simple notes on the environment as it affects commercial fishing.

4. Note the fishing conditions.

5. Carry out special sampling which does not interfere with commercial operations, such as underway plankton sampling, bottom sampling and echo sounding.

6. Instruct and assist fishermen in using new gear, locating fish, etc.

When planning these trips the observer must know the plans of the commercial fisherman and adjust his activities accordingly. The observer can usually take a certain number of instruments, and partly complete the cruise and station logs, the meteorology data sheet, and the fishing log.

It is of value when fishermen are interviewed on these trips to ascertain from them why they fish on a particular ground, their special observations on fish and gear behavior, their knowledge of average fishing and environmental conditions, and other matters bearing on the fishing operations.

1.1.2.4 Cruises in research vessels

After the field-party chief has made up a cruise plan in co-operation with the ship's master, the plan should be approved by the head of the institution.

The field-party chief is responsible for any eventual modifications of the plan if the conditions so require. He also assigns scientific and technical staff to their duties.

The master is responsible for provisioning, fueling and preparing the vessel. In general, the small space in a shipboard laboratory and on deck must be carefully planned for every trip to suit the work which it is intended to do.

The field-party chief also prepares the sailing order (usually three copies - office, master, cruise file). The sailing order contains the following information:

1. Departure date.
2. Approximate date of return.
3. Approximate sailing route.
4. Description of work to be done.
5. Operational schedule.
6. Personnel list.

In addition, the following information can be included:

7. List of gear.
8. Records and reports to be filled.
9. Special instructions.

To obtain the fullest information from the cruise, planning must continue during the cruise, especially when the original plans have to be modified according to the data obtained and other conditions.

1.1.3 Pattern of observations

A station is a geographically identifiable point at which operations are carried out, or from which certain operations (e.g., net hauling) are begun on a single occasion. If a particular point is returned to for repetition of operations, or for a new set of them, it is to be regarded as a new station unless a set of stations has been selected in special pattern and each is returned to a number of times. In this case serial identification must be used within the station identification. The position of each station actually occupied should be ascertained carefully and recorded in the log of the expedition. The stations to be occupied during an expedition may be fixed in definite pattern beforehand on the basis of evidence on the distribution of some feature, e.g., of salinity, current, or some organism that is regarded as an ecological indicator. Alternatively, the stations may be decided upon during the expedition as conditions permit and as contemporary observations suggest.

The following suggestions are often useful to determine the pattern of stations.

1. The section of stations should usually cross the isolines of environmental or biological distribution of properties.
2. The distance between the stations depends on the magnitude of change of the properties within this distance which are to be measured.

3. The frequency of sampling in routine stations depends on the rate of change of properties with time.

4. Hydrographical stations and/or other observations of the environment should be made where biological sampling is done or experimental fishing conducted.

5. All work which can be done before reaching the station, such as fixing thermometers, preparing log sheets, checking bottles, etc. should be done while underway.

6. Previous experiences and information should be used to form the sampling patterns.

In an expedition plan the operational plan is a set of instructions to the technical (scientific) staff of the expedition, and should be explicit as to what is to be done, where and when, and what modifications of the plan may be made.

The operational plan stands as part of the expedition plan, as in the following framework.

EXPEDITION PLAN

Expedition number (cruise, field trip or visit)

to (area, locality or position)

Planned duration: commencing ending

Objectives:

Staff:

Equipment:

- Vessel
- Fish searching gear
- Fishing gear
- Meteorological equipment
- Hydrographical equipment
- Biological equipment

Operational plan:

- Operations to be conducted
- Itinerary
- Station list (or plan) and operational routines

Records:

1.1.4 Lake, stream and river basin surveys with respect to fisheries

1.1.4.1 Purposes of inland fisheries surveys

The purpose of a limnological and fisheries survey is to ascertain with a minimum expenditure of time and money the essential physical, chemical and biological characteristics of a body of water. On the basis of this information critical studies in limnology and fisheries can be instituted, or a fish management program can in some instances be undertaken immediately.

Having attained the scheduled information, the survey provides the factual basis for:

(*a*) establishment (or reorientation) of policy or program, and

(*b*) formulation of a program of management or developmental action, which, with respect to fisheries, is designed to increase production or improve the efficiency of fishing operations. (There are, of course, instances where preservation rather than increased production may be all that is possible.)

It must also be emphasized that the short-term survey rarely permits an adequate evaluation of the size or composition of the fish population or of the harvest. While certain attributes of the population can be determined by rapid sampling, detailed knowledge of the dynamics of fish populations and the other biota depend upon the employment of studies of such complexity or duration that they fall outside the terms of reference of most surveys.

One can sum this up by saying that the amount of time and effort that can be expended and the methods to be employed are largely functions of the purposes to be attained and the ever-prevailing factors of economy and administrative pressure.

It is obvious, therefore, that it is impossible to construct an ideal or universal plan or outline which will be applicable for a survey of any type of lake in any part of the world or which can meet either the demands for a very short survey or the desires (of many scientists) for very long-range studies. In short, one cannot meet the needs of all workers and, for that matter, it is not within the capabilities of all workers to perform the type of work that might ideally be contemplated.

It is possible, however, to present an outline, general in nature, but with considerable detail, which can:

(*a*) provide a guide to (or checklist of) the types of information that might be secured for such a survey, and

(*b*) function as an outline which can be used in organizing a report which presents the information secured and enables one to draw conclusions and make recommendations.

Additions or deletions can be made, depending upon the scope, kind and needs of the project. For a very rapid survey, only a little of this information need be collected: indeed, probably only a little of it can be obtained. On the other hand, those making a long and intensive study may borrow heavily from the suggested material.

A certain amount of repetition in the headings or items of information is purposeful. It merely indicates that there are multiple ways of presenting or discussing the same data, and obviously, each author will have his own opinion as to the best placement for his purposes.

It may also be noted that it is usually most convenient to record much of the original data on specially designed lake survey forms or field sheets. The data can then be stored on these same sheets or can be transferred to other forms for filing or can be used as the bases for a more extended report. The outline may be useful in designing such forms.

For purposes of study, especially in the case of long streams, it is usually convenient, and often necessary, to divide the stream into sections and treat each section more or less as an individual unit. The boundaries of the sections should be selected on the basis of ecological and political considerations, and, where possible, with a view toward the eventual designation of the sections as management units.

While each section can be described separately, more or less according to the suggestions given in the outline it is, of course, also necessary to consider and describe the stream as a whole.

1.1.4.2 Outline for a lake survey

Abstract (A brief abstract of the report should be given here)

1. Introduction
   - 1.1 Purpose of the survey
   - 1.2 Background material (previous surveys, etc.)
2. Acknowledgments
3. Account of the present survey
   - 3.1 Agencies concerned
   - 3.2 Personnel and leadership
   - 3.3 Time and duration (chronological account)
   - 3.4 Sources of data
   - 3.5 Methods
     - 3.51 List of stations
     - 3.52 Collecting methods
     - 3.53 Sampling program
     - 3.54 Analytical methods
     - 3.55 Treatment of data
     - 3.56 Storage of data
4. General description of the lake and its basin
   - 4.1 Name of lake (including synonyms)

4.2 Location, accessibility, ownership, use

4.21 Geographical designation
4.22 Elevation (altitude)
4.23 Roads, trails, railroads, airports or landing strips
4.24 Distances from major points
4.25 Boat landings, ports, fishing harbors
4.26 Name of owner or controller of accessibility and fishing
4.27 Uses of the lake (fishing, recreational, irrigation, etc.)

4.3 History of the lake with particular respect to its fishing
4.4 Geological history
4.5 Drainage basin

4.51 Area
4.52 Topography
4.53 Basic rocks and soil
4.54 Vegetational cover
4.55 Climatic conditions

4.551 Air temperature
4.552 Precipitation
4.553 Evaporative rate
4.554 Humidity
4.555 Wind
4.556 Air pressure
4.557 Sunshine

4.56 Drainage affinities and lake origin
4.57 Watershed use and degree of development (industrialization, urbanization, etc.)
4.58 Inlets

4.581 Length
4.582 Widths
4.583 Depths
4.584 Bottom type
4.585 Flow (in m^3)
4.586 Water temperatures
4.587 Stream gradient or slope
4.588 Barriers to fish migration
4.589 Relationship to lake fishery
4.5899 Etc.

4.59 Outlets

(As for Inlets)

5. Physical character of the lake (nature of the physical environment)

5.1 Morphometry (based on a bathymetric map showing soundings and to scale)

5.11 Length

- 5.12 Breadth
- 5.13 Depths (maximum, mean, relative)
- 5.14 Area, surface
- 5.15 Area, subsurface (within isobaths)
- 5.16 Shoreline length
- 5.17 Shoreline, development of
- 5.18 Basin slope (between isobaths and mean slope) and profiles
- 5.19 Volume
  - 5.191 Volume, development of
  - 5.192 Rates of change of area with respect to volume

5.2 Morphology

- 5.21 Shape
- 5.22 Insulosity
- 5.23 Shore processes
  - 5.231 Cliff, beach, littoral shelf
  - 5.232 Spits, bars
  - 5.233 Bays
  - 5.234 Deltas
- 5.24 Sublacustrine elements
  - 5.241 Shelves
  - 5.242 Depressions
  - 5.243 Channels

5.3 Wind: velocity, direction, duration

5.4 Thermal properties

- 5.41 Water temperatures
  - 5.411 Surface
  - 5.412 Subsurface
- 5.42 Stratification and turnover
- 5.43 Heat budget
- 5.44 Ice conditions

5.5 Hydromechanics (water movement)

- 5.51 Currents: velocity and direction
- 5.52 Density currents
- 5.53 Fluctuation in level
- 5.54 Seiches
- 5.55 Tides

5.6 Color (true color)

5.7 Light penetration (as determined by limit of visibility tests [Secchi] or light measurement [photometer])

5.8 Turbidity (as determined by silica standard, platinum-wire method, turbidimetric methods)

5.9 Bottom materials

- 5.91 Types
- 5.92 Extent

6. Chemical character of the lake (nature of the chemical environment)

- 6.1 General hydrochemistry
  - 6.11 Hydrogen-ion concentration (pH)
  - 6.12 Alkalinity
    - 6.121 Methyl-orange (bound CO_2)
    - 6.122 Phenolphthalein
  - 6.13 Total dissolved solids
    - 6.131 Nonvolatile solids (ash content)
    - 6.132 Loss on ignition
  - 6.14 Salinity
  - 6.15 Total hardness
  - 6.16 Specific conductivity
  - 6.17 Redox potential
  - 6.18 Biochemical oxygen demand (BOD)
  - 6.19 Total organic content
  - 6.199 Equilibrium between water and mud
- 6.2 Dissolved gases
  - 6.21 Oxygen
  - 6.22 Carbon dioxide
  - 6.23 Others (methane, hydrogen sulfide, nitrogen, ammonia, sulfur dioxide, carbon monoxide, etc.)
- 6.3 Dissolved (inorganic) solids
  - 6.31 Phosphorous compounds
    - 6.311 Total phosphorus
    - 6.312 Soluble phosphate phosphorus
    - 6.313 Sestonic acid-soluble phosphate phosphorus
    - 6.314 Organic soluble (and colloidal) phosphorus
    - 6.315 Organic sestonic phosphorus
  - 6.32 Nitrogen compounds
    - 6.321 Molecular nitrogen in solution
    - 6.322 Organic nitrogen compounds
    - 6.323 Ammonia as NH_4 + and NH_4OH
    - 6.324 Nitrite
    - 6.325 Nitrate
  - 6.33 Important cations
    - 6.331 Sodium (Na)
    - 6.332 Potassium (K)
    - 6.333 Magnesium (Mg)
    - 6.334 Calcium (Ca)
    - 6.335 Copper (Cu)
    - 6.336 Iron (Fe)
    - 6.337 Zinc (Zn)
    - 6.338 Manganese (Mn)
    - 6.339 Etc.

6.34 Important anions

6.341 Bicarbonate (HCO_3)
6.342 Sulfate (SO_4)
6.343 Chloride (Cl)
6.344 Carbonate (CO_3)
6.345 Silicate (SiO_4)

6.4 Organic compounds

6.41 Organic nitrogen (see 6.3)
6.42 Organic phosphorus (see 6.3)
6.43 Fats (ether extracts)
6.44 Vitamins
6.45 Etc.

6.5 Water pollution

6.51 Source
6.52 Type
6.53 Severity
6.54 Control

7. Biological character of the lake (see also 8, 9 and 10 below)

(The influence of the physical and chemical factors described above may be discussed here or the discussion may be deferred to 14.)

Other points requiring discussion may include:

7.1 Habitat, zones, associations
7.2 Nutrient cycles
7.3 Food chains
7.4 Measurements of basic organic production
7.5 Energy cycles

8. Flora and fauna (exclusive of vertebrates)

[This section may contain:

Lists of species (or other groups)
Records of their abundance (qualitative; quantitative; seasonal)
Records of their distribution (vertical; horizontal; seasonal)]

8.1 Bacteria and fungi
8.2 Plankton (macro-, net-, nanno-, total)

8.21 Phytoplankton
8.22 Zooplankton

8.3 Neuston
8.4 Pleuston
8.5 Nekton (other than fishes, for which see 9)
8.6 Periphyton
8.7 Rooted aquatic vegetation (phytobenthos)

8.71 Marginal (shore)
8.72 Emergent
8.73 Submergent

8.8 Vegetation-inhabiting animals
8.9 Bottom fauna (zoobenthos)

9. Fish fauna

Presentation of the data to be assembled here can follow various patterns, for example:

(*a*) List of species including scientific, and official common names and vernacular names; and/or

(*b*) Species grouped by communities, associations, etc.; i.e., according to:

(i) type of nutrition
(ii) habitat occupied
(iii) etc., and/or

(*c*) Species grouped for purposes of fish management, selecting some combination from categories such as:

Commercial
Sport (game fishes, pan fishes)
Forage
Coarse (rough)
Obnoxious
Desirable
Undesirable, etc., and/or

(*d*) A rather extended treatment can be used for each individual species.

9.1 Name (scientific, common, vernacular)
9.2 Distribution (within the lake)
9.21 Ecological characterization of the area
9.22 Differential distribution

(Areas occupied by eggs, larvae and other junior stages: annual variations in these patterns, and seasonal variations for stages persisting over two or more seasons. Areas occupied by adult stages: seasonal and annual variations of these.)

9.3 Bionomics and life history
9.31 Reproduction
9.311 Maturity (age and size)
9.312 Fecundity
9.313 Spawning (seasons, frequency, time, etc.)
9.314 Spawning grounds
9.32 Larval history

9.33 Adult history
- 9.331 Longevity
- 9.332 Hardiness
- 9.333 Competitors
- 9.334 Predators
- 9.335 Parasites and diseases

9.34 Nutrition and growth
- 9.341 Feeding
- 9.342 Food
- 9.343 Condition
- 9.334 Growth/age

9.35 Behavior
- 9.351 Migration and local movements
- 9.352 Schooling
- 9.353 Reproductive habits

10. Other vertebrates

(A treatment somewhat similar to that used in 9 may be followed. Emphasis should be placed on the relationship of these animals to the fishery.)

11. Fish population studies

11.1 Structure
- 11.11 Sex ratio
- 11.12 Age composition
- 11.13 Size composition

11.2 Size and density
- 11.21 Average size
- 11.22 Changes in size
- 11.23 Average density
- 11.24 Changes in density

11.3 Natality and recruitment
- 11.31 Natality
- 11.32 Natality rates

11.4 Mortality, morbidity
- 11.41 Rates of mortality
- 11.42 Factors or conditions affecting mortality
- 11.43 Factors or conditions affecting morbidity
- 11.44 Relation of morbidity to mortality rates

11.5 Dynamics of population

11.6 Relation of population to community and ecosystem, biological production, etc.

12. Exploitation

12.1 Commercial fishing

12.11 Number of fishermen
12.12 Fishing equipment
12.121 Gear
12.122 Craft
12.13 Fishing areas
12.131 Geographic
12.132 Depth ranges
12.14 Fishing seasons
12.15 Fishing operations and results
12.151 Effort and intensity
12.152 Selectivity
12.153 Catches, landings (statistics)
12.16 Processing
12.17 Distribution
12.18 Marketing
12.19 Licensing or issuance of permits

12.2 Sport fishing

(In making studies of the exploitation of sport [game] fishes, recourse is usually had to a creel census or some other method of sampling.)

12.21 Creel census information
12.211 Fishermen
12.2111 Number
12.2112 Type (classed by age, sex, geographical origin, goal, type of gear used)
12.212 Gear and methods
12.213 Species composition of catch
12.214 Size composition of catch
12.215 Fishing effort or pressure (man-hours, etc., of fishing, fishermen or man-hours per unit surface area, etc.)
12.216 Fishing success (catch per unit of effort: fisherman-day or fisherman-hour, fisherman-season)
12.217 Harvest (total catch in numbers and/or weight; catch per unit surface area, etc.)
12.218 Distribution and characteristics of the fishing (geographical, seasons, time of day, etc.)

(In addition to the above types of information it may also be important to measure the economic value of sport fishing in a lake [or any given area] as expressed in monetary terms. Such economic evaluation involves the collection of various data such as those listed below.)

12.22 Economic value

12.222 Number of fishermen
12.223 Number of days fished
12.224 Expenditures per fisherman per trip or season for:

12.2241 Fishing tackle and other equipment
12.2242 Trip expenditures, transportation, food, lodging, etc.
12.2243 Licenses, permits, leases
12.2244 Other pertinent expenditures

12.3 Subsistence fishing

(List whatever data it appears advisable to collect or which can be collected, using 12.1 and 12.2 above as guides.)

13. Fisheries management and regulations

13.1 Regulations

13.11 Fishing seasons
13.12 Size limits
13.13 Periodic (daily, weekly, seasonal, etc.) limits
13.14 Restrictions on sex, condition, etc.
13.15 Closed or restricted areas
13.16 Gear or craft restrictions

13.2 Control or alteration of physical features of the environment

13.21 Regulation of flow (inlets and outlets)
13.22 Control of water levels
13.23 Control of erosion and silting
13.24 Fishways
13.25 Barrier removal and/or erection
13.26 Fish screens
13.27 Improvement of spawning grounds
13.28 Construction of fish shelters, attractors, etc.
13.29 Improvement of habitat in the inlets or outlets

13.3 Control or alteration of chemical features of the environment

13.31 Pollution control
13.32 Salinity control
13.33 Fertilization

13.4 Control or alteration of the biological features of the environment

13.41 Control of aquatic plants
13.42 Introduction of foods (plant and invertebrate)
13.43 Introduction of forage fish
13.44 Control of disease and parasites
13.45 Control of predation and competition
13.46 Population manipulation

13.5 Artificial stocking and feeding

13.51 Initial introduction

13.52 Maintenance stocking
13.53 Feeding
13.54 Introduction of exotic species
13.6 Other methods and measures

14. Discussion and conclusions

15. Recommendations

16. Literature cited

17. Appendixes (supporting data, maps, photographs, diagrams, tables, special studies, etc.)

1.1.4.3 Outline for a stream survey

Abstract (a brief abstract of the report should be given here)

1. Introduction

   1.1 Purpose of the survey
   1.2 Background material (previous surveys, etc.)

2. Acknowledgments

3. Account of the present survey

   3.1 Agencies concerned
   3.2 Personnel and leadership
   3.3 Time and duration (chronological account)
   3.4 Sources of data
   3.5 Methods
      3.51 Division of the stream into sections
      3.52 List of stations
      3.53 Collecting methods
      3.54 Sampling program
      3.55 Analytical methods
      3.56 Treatment of data
      3.57 Storage of data

4. General description of the stream and its basin

   (Here, or at some other place in the report, it may be advisable to present a brief picture of the entire stream before proceeding with the detailed treatment. This is, perhaps, best accomplished by tracing its course from source to mouth. Major emphasis may be placed on describing its size and type, the physiography, etc.)

4.1 Name of stream (including synonyms)
4.2 Location accessibility, ownership, use
4.21 Political designations (country, state, province, county, district, etc.)
4.22 Geographical designation
4.23 Elevation (altitude) at source, mouth and other points; especially upper and lower ends of each section
4.24 Roads, trails, railroads, airports, landing strips
4.25 Distances from major points
4.26 Boat landings, ports, etc.
4.27 Name of owner(s), controller(s) of accessibility and fishing
4.28 Uses of the stream
4.3 History of the stream with particular respect to its fishery
4.4 Geological history
4.5 Drainage basin
4.51 Area
4.52 Topography
4.53 Basic rocks and soil
4.54 Vegetational cover
4.55 Climatic conditions
4.551 Air temperature
4.552 Precipitation (rain, snow)
4.553 Evaporative rate
4.554 Humidity
4.555 Wind
4.556 Air pressure
4.557 Sunshine
4.56 Tributaries (streams, lakes, etc.)
(To be described briefly as summarized in the outlines or to be made the subject of separate surveys if deserved.)
4.57 Distributaries and related waters (overflow areas, oxbow lakes, etc.)
(As for tributaries or lakes.)
4.58 Watershed use and degree of development (industrial, urbanization, etc.)

5. Physical character of the stream

5.1 Stream measurements
5.11 Length of stream and sections
5.12 Widths (of channel and of water surface itself)
5.13 Depths (of channel and of water)
5.14 Area
5.15 Stream profiles and gradients
5.16 Transverse profiles
5.17 Meander factor
5.18 Variations in water level (low, high, floodwater levels)

5.2 Stream typology

(In characterizing the stream it is useful to describe some of the following.)

5.21 Source of water supply (surface, runoff from rain or snow, springs, groundwater seepage, glaciers, diversions from other waters, return irrigation water, etc.)

5.22 Fluvial stage, physiographically

5.23 Stream margins or banks (type, height, composition, cover, vegetation, shade, etc.)

5.24 Stream components (pools, flats, runs, riffles, rapids, stickles, cascades, etc.), especially their number, size and relative frequency

5.25 Type of flow and velocity

5.251 Whether smooth, broken, cascading, turbulent, etc.; or permanent, intermittent

5.252 Velocity of current

5.253 Tides (as in estuaries)

5.254 Time lags

5.3 Stream bed (bottom) materials

5.31 Types

5.32 Extent

5.33 Use or suitability as spawning grounds

5.4 Rate of flow and volume

5.41 Rate of flow (m^3 sec^{-1}) (extremes and means; seasonal, diurnal and nocturnal fluctuations)

5.42 Volume or runoff (within a given time interval; extremes and means; as measured in acre-feet, milliards, etc.)

5.5 Thermal properties

5.51 Water temperatures

5.52 Thermal gradient

5.53 Snow and ice conditions

5.6 Color and light penetration

5.7 Turbidity

5.8 Barriers and deterrents (to fish migration)

5.9 Diversions

6. Chemical character of the stream

(See the outline for a lake survey and select appropriate items. Usually one does not make as detailed chemical analyses of streams as of lakes unless some special circumstances prevail.)

7. Biological characteristics of the stream

(The influence of the physical and chemical factors described above in determining the biological conditions of the stream [growing conditions,

food production, suitability for spawning, etc.] may be discussed here, or referred to 14.)

8. Flora and fauna (exclusive of vertebrates)
   (See the outline for a lake survey; select appropriate items or modify as necessary. The terrestrial fauna [primarily insects] also deserve consideration as fish foods.)

9. Fish fauna
   (See the outline for a lake survey; select appropriate items or modify as necessary.)

10. Other vertebrates
    (See the outline for a lake survey.)

11. Fish population studies
    (See the outline for a lake survey.)

12. Exploitation
    (See the outline for a lake survey; select appropriate items and modify as necessary.)

13. Fisheries management and regulations
    (See the outline for a lake survey; select appropriate items.)

14. Discussion and conclusions

15. Recommendations

16. Literature cited

17. Appendixes (supporting data, maps, photographs, diagrams, tables, special studies, etc.)

1.1.4.4 Outline for a river basin survey

Abstract (a brief abstract of the report should be given here)

1. Introduction
   - 1.1 Purpose of the survey
   - 1.2 Background material
     - 1.21 Brief description of water and land use within the basin and the agencies concerned
       - 1.211 Past

1.212 Present
1.213 Projected

(This should include statements of the general effect of these uses with respect to the fishery and a detailed history of the applications or steps taken to undertake such development.)

1.22 Previous surveys with respect to fisheries

2. Acknowledgments

3. Account of the present survey
   - 3.1 Agencies concerned
   - 3.2 Personnel and leadership
   - 3.3 Time and duration (chronological account)
   - 3.4 Area covered; itinerary
   - 3.5 Sources of data
   - 3.6 Methods
     - 3.61 Division of the area for coverage
     - 3.62 List of stations
     - 3.63 Collecting methods
     - 3.64 Sampling program
     - 3.65 Analytical methods
     - 3.66 Treatment of data
     - 3.67 Storage of data

4. Description of area affected
   - 4.1 General description of drainage basin

     (See 4 of the outline for a stream survey and select appropriate items.)
   - 4.2 Description of the stream(s) and/or lake(s) affected

     (See 5, 6, 7 and 8 of the outlines for stream surveys and lake surveys and select appropriate items.)

5. Description of the fishery and its management

(Again, the stream and lake outlines, 9, 11, 12 and 13, can be used as guides.)

Emphasis should be placed on describing:

1. All facts concerning the bionomics and life history of the species involved which are of pertinence with respect to evaluating the effect of the proposed river basin development upon the stocks.

2. The productivity of the stream as measured in units of fish
   - (*a*) Past
   - (*b*) Present
   - (*c*) Potential (as under improved management or changed natural conditions)

3. Economic value of the resource as measured in various ways

(*a*) Commercial catch

(i) Number and/or weight of fish
(ii) Price paid to fishermen
(iii) Wholesale value of the product
(iv) Retail value of the product
(v) "Profits" made at various producer and distributor levels
(vi) Etc.

(*b*) Sport catch

(i) Number and/or weight of fish
(ii) Value as determined by assigning a monetary value to each unit taken
(iii) Value based on expenditures incurred in angling
(iv) Etc.

(*c*) Subsistence catch

(i) As in (*b*) above
(ii) As in (*b*) above
(iii) Etc.

4. Other values

(*a*) Nutritional (e.g., in terms of protein)

(i) to man
(ii) to wildlife

(*b*) Recreational

(*c*) Scientific

(*d*) Aesthetic

6. Proposed developments [1]

(This may begin with an introductory statement as to the purpose and scope of the project as a whole, to be followed by a description of the individual components of the project, i.e., each dam, diversion, reservoir, etc., using the outlines given below.)

6.1 Dams

6.11 Name
6.12 Location
6.13 Ownership and controlling agency (if different)
6.14 Age (dates: construction started, construction completed, storage commenced, lake first filled; dam first became a barrier to fish migration; initial operation; etc.) [2]

---

[1] This portion of the outline can, of course, be used to describe existing development.
[2] For projected dams, use scheduled or anticipated dates.

6.15 Use (irrigation, hydroelectric power, water power, flood control, domestic supply, industrial supply, compensation, percolation, stream-flow maintenance, fishing, recreation, salinity control, debris control, etc.)

6.16 Description

6.161 Type

6.162 Dimensions and elevations

6.1621 Height and elevations (at stream bed, crest, spillway crest, etc.)

6.1622 Length of crest

6.1623 Thickness (at crest, at base)

6.163 Slopes (horizontal to unit vertical on downstream and upstream sides)

6.164 Facings and apron (downstream and upstream)

6.165 Foundation formation

6.166 Spillway

6.1661 Discharge (maximum capacity, minimum expected)

6.1662 Controls (type, number and description; radial gates, drumgates, flashboards, etc.)

6.17 Outlets (see also 6.18 and 6.3)

6.171 Type and use of water (canals, tunnels, sluice gates, penstocks, river outlets, "fish water" outlets, special outlets as for fishways, fish flumes, etc.)

6.172 Dimensions and elevations

6.173 Discharge (maximum capacity, minimum expected)

6.174 Controls (type, number and description)

6.175 Fish screens or deflectors (mechanical, electrical, etc.) (Describe fully location, type, dimensions, size of mesh or bars, type of cleaners, bypasses, etc.)

6.176 Special devices (other than screens) used for fish protection or fish passing downstream

6.18 Operation schedule of dam and outlets

6.181 Periods and amounts of discharge

6.2 Fishways, fish locks, fish lifts, etc.

(Describe fully: location, type, dimensions, elevations, collection systems, operation schedule, counting facilities, etc.)

6.3 Diversions or conduits

6.31 Name

6.32 Location and route

6.33 Ownership and controlling agency (if different)

6.34 Age (dates of construction, initial operation)

6.35 Use (see 6.15)

6.36 Headworks or intake

6.361 Controls

6.362 Fish screens or deflectors
6.363 Special features (desilting, etc.)
6.364 Operation schedule

6.37 Description of conduit itself

6.371 Type (canal, tunnel, etc.)
6.372 Dimensions (length, width, depth, side slopes)
6.373 Bottom, facings, linings, etc.
6.374 Capacity (maximum, normal discharge, minimum expected)
6.375 Gradients
6.376 Current velocity
6.377 Drops, checks or barriers en route

6.38 Connections with other waters (including spill): bypasses, pumps, drainage canals, etc.

6.39 Fishing

6.391 Amount of fishing water
6.392 Details of fishery
6.393 Effect of operations (weed control, dredging, desilting, drainage, etc., on fishery)

6.4 Power plants

6.41 Name
6.42 Location
6.43 Ownership and controlling agency (if different)
6.44 Age (dates: of construction, of initial operation, etc.)
6.45 Use
6.46 Description

6.461 Head
6.462 Penstocks (capacity or rate of flow)
6.463 Turbines (number, type, clearances, depth setting, etc.)
6.464 Operating capacity (Kw, HP)

6.47 Forebays
6.48 Afterbays and/or tailwaters
6.49 Future developments

6.5 Reservoirs

(The outline for a lake survey can be used as a guide to the description of a reservoir, existing or projected.)

Since reservoirs, in general, fluctuate to a much higher degree than do natural lakes, special attention should be paid to: outlining the fluctuation schedule; describing the morphometry, morphology, thermal properties, hydromechanics, etc., at different water levels; determining the effect of such changes on the biological character of the lake and its fishery.

Aside from the items already enumerated in the lake outline it may be useful to consider:

(i) Preparation of the terrain before flooding

(ii) Provision for dead storage
(iii) Possibility of draining the reservoir
(iv) Expected sedimentation rate

6.6 Other types of land and water use developments that have a direct or immediate effect upon the watercourses

(Describe all of these in sufficient detail so that the effect on the fishery can be evaluated.)

6.61 Drainage works
6.62 Dredging
6.63 Stream-course alteration
6.64 Leveeing, diking, construction of flood walls, etc.
6.65 Aquatic vegetation control
6.66 Spoil deposition
6.67 Lowering of natural lake levels
6.68 Changes in streams due to road construction (culverts, channel construction, etc.)
6.69 Etc.

6.7 Other developments or changes resulting from development

(Here one might discuss the planned developments [or the changes that will occur as a result of the initial development] in land and water use which may also have an effect on the fishery.) [3]

Among these may be listed the changes or developments in:

(i) Hunting (for subsistence)
(ii) Grazing
(iii) Agriculture
(iv) Forestry
(v) Mining
(vi) Soil conservation
(vii) Environmental sanitation
(viii) Travel and transportation
(ix) Industrialization
(x) Urbanization
(xi) Recreation
(xii) Changes in (human) population (growth or decline, resettlement, etc.)

7. Effect of proposed (and/or existing) developments on the fishery

(Here one should list and describe the effects that any of the structures or

[3] As outlined, the distinctions between 6.6 and 6.7 are somewhat arbitrary. The developments listed under 6.7 may, perhaps, be said to act only indirectly on the watercourses and hence on the fishery. Nevertheless the effect of some of these developments or practices on the aquatic resources may be of the greatest importance.

operations discussed in 6 have on the environment and the fishery. Some of the possible effects are listed below as a guide.)

7.1 Dams

7.11 May constitute physical barriers or deterrents to fish migration [4]

7.111 Upstream

7.112 Downstream

7.12 May cause physical injury to or result in death to fish falling over the spillway

7.13 May drown out the present stream fishery above the dam

7.14 May create new and enlarged fishing areas (reservoirs) (see 7.5)

7.15 By altering the magnitude and chronology of the flows below them, they may:

7.151 Reduce or increase the space available for fish and/or the fishing area

7.152 Reduce or increase the size and/or quality of spawning and nursery grounds, or withhold access to them

7.153 Reduce or increase the food-producing areas or change their components

7.154 Produce changes in water temperature

7.155 Produce changes in water chemistry

7.156 Produce changes in water turbidity

7.157 Change the capacity of the stream for self-purification

7.2 Diversions or conduits may:

7.21 Result in loss of fish which enter them

7.22 Result in the creation of additional aquatic habitat and fishing areas

7.23 Result in the introduction of aquatic organisms into drainage basins where they did not formerly reside

7.3 Other appurtenances or devices connected with dams, desilting devices, for example, may harm fish which enter them

7.4 Power plants

7.41 Damage to upstream migrants may occur if they enter the draft tubes of power plants and find their way into the turbines

7.5 Reservoirs

7.51 May possess an area and volume of water with a more productive capacity than the original stream area, albeit usually for a different fauna

7.52 Changes in water level may: result in the stranding of fish, affect food production, affect spawning and spawning areas, permit undesirable fish to ascend into waters where they were not resident, etc.

---

[4] Although their effect as deterrents is almost always unfavorable, in some cases they may act as barriers to undesirable fishes which could otherwise invade productive upstream areas.

7.6 Other types of development having a direct or immediate effect on water courses and (thereby) on the fishery

(Describe the effects of the developments listed in 6.6.)

7.7 Other types of development or changes resulting from development

(Describe the effect on the fishery of the developments or changes listed in 6.6.)

For example, changes in land practices associated with grazing, agriculture or forestry may result in increased or decreased runoff or erosion. The use of insecticides in intensive farming or the control of forest insects may harm the fishery. Increased land fertilization may change the water quality of the basin. Road construction may increase fishing intensity on areas already overfished or permit useful exploitation of other areas.

Industrialization may increase pollution problems.

8. Discussion and conclusions

9. Recommendations

(See Dill and Kesteven (1958) for suggestions as to methods of minimizing danger to aquatic stocks and gaining the best results from changed environmental conditions.)

10. Summary

11. References
    11.1 Literature cited and/or used for the survey
    11.2 Maps
    11.3 Plans

12. Appendixes (supporting data, maps, photographs, diagrams, tables, special studies, etc.)

1.2 RECORDS AND REPORTS

1.2.1 **Records**

We divide the records of expeditions into three main groups. Firstly, those of the expedition as a whole, comprising the diary of the technical staff and the cruise and station log (of a ship); secondly, the records of the primary operations; thirdly, the records of the secondary operations.

Forms are necessary and useful in this kind of work, where so much is routine, in that they systematize the recording operation, and to some extent simplify it.

A well-designed form has certain general characteristics conforming to a number of criteria.

First, it provides space for recording all the information required concerning the operation for which it is designed.

Second, it does not call for the recording of information that is better recorded in connection with some other operation, and it provides for easy cross-reference between sets of records.

Third, in the case of forms relating to techniques, the design permits the entry of information in the sequence in which the operations of the techniques are carried out.

Fourth, it does not require or invite repetition of information common to a number of items, nor is space wasted by repetition; for example, if many operations are carried out at a station, the station number should be shown once as common to all these operations and not repeated for each, and if possible there should be a separate sheet (or group of sheets) for each station with appropriate space for station identification. A common error in form design is to provide a column for information that is entered only once, and for which, therefore, a single line, or box would be sufficient.

Fifth, in the case of a form for data that will be treated statistically, as far as possible it should serve the purposes of the statistical operatives as well as of the field worker.

Sixth, it is of size, shape and material suitable for the conditions under which it will be used, and for the convenience of the user.

Seventh, it conforms as far as possible to statisticians' norms concerning size of spaces, width of column, and layout.

Finally, it is of utmost importance that each set of records (and in fact, that each sheet) should be self-contained and completely clear, and must be usable without reliance on memory. Each form should be designed to achieve this.

The basic scientific record of an expedition is the diary, an hour-by-hour and day-by-day record of the activities and observations of the scientific staff of the expedition. Note is kept in the diary of general movements of the expedition, stations occupied (with their position), operations performed showing the objects (kind and number) to which various techniques have been applied, and any general observations made by the scientific staff (e.g., of whales or birds seen, particular meteorological and hydrographic phenomena). On cruises the scientific diary is supplemented, and in some respects checked by the cruise log, which records all movements in detail, shows stations occupied and notes the operations performed at each, and records information on the management of the expedition.

In this Section we deal with only the cruise and station log, leaving to appropriate other Sections a discussion of the specialized records, to be kept for particular sets of operations.

Form 1. - Cruise and station log

(*a*) *Vessel*.....

(*b*) *Cruise No.*.....

1 Date	2 Hour start	3 Hour finish	4 Position Lat. 4.1	4 Position Long 4.2	5 No. of Station	6 Logs filled 6.1 Met. log	6.2 Orig. Oceanogr. log	6.3 Plankton log	6.4 Fishing log	6.5	6.6 Photos	7 Gear overboard	8 Remarks and special observations (Fish schools, birds, detritus and plankton, discoloration of water, notes about fishing fleet, etc.)

Notes on Form 1. Cruise and station log [5]

This log is a master record of the cruise. It should be kept by the navigation officer assisted by the scientific watch, in duplicate, by means of a carbon copy. Basically it lists and locates the stations and records the kinds of operations carried out at each by showing in columns 6.1 to 6.6 the scientific logs completed.

4. For " underway " stations, give position at commencement of the scientific operation for which the station is taken.

6. Indicate with x the logs in which notes are entered for each position and/or station.

7. Record the items of gear used.

8. Indicate the change of course and observations on birds, fish schools and pleuston sighted. (See instructions in Section 2.) For longer descriptions use the reverse side of the log, numbering every note so that it is clear to which observation, station and position the remark belongs.

It is necessary to emphasize the importance of careful and systematic storage of all field records and it is further to be advocated that each institution should maintain a field records unit in which all records are registered and stored when not in use. The field records unit should keep a register of movements of each log diary and set of papers. Such a system has many advantages over the system in which each officer responsible for the original observations retains the records of them as his personal property.

Many laboratories have their own card systems for the recording of data. Such card systems exist also regionally. An example is the mechanized punch card system of hydrographical data of the International Council for the Exploration of the Sea and the BT data cards of the U.S. Navy Hydrographic Office, etc.

The following points on the keeping of records and reports are generally valid in a wide variety of conditions:

1. No original data are to be disposed of until all possible need for reference to the data has ceased to exist.

2. Do not deviate from a prescribed schedule without real justification. Consistency is very important in both the obtaining and recording of field data. When doubts arise as to correct procedure consult your immediate supervisor.

[5] In these notes the numbers refer to the column of the table to which the note relates; letters refer to entries above the columns.

3. Field data are to be entered in the books in the prescribed manner the same day that they are recorded in the field.

4. A diary is to be kept by all members of the fish research section.

5. In some cases, estimates of one kind or another are in order. When figures represent an estimation rather than an actual count or measurement, place an E after the figures.

6. New projects. When a new project is to be undertaken, the following procedure will apply:

(*a*) A complete project outline will be submitted to the appropriate authority or office for approval.

(*b*) The individual to whom the project is assigned should receive pertinent data on objectives, personnel, equipment and funds available for the project.

(*c*) The person to whom the project is assigned should take whatever time is necessary to review the literature on the subject and examine thoroughly, in the field, the area to be studied.

(*d*) The person to whom the project is assigned shall then be responsible for carrying out the project and shall keep the supervisor advised of progress.

1.2.2 **Writing of reports and presentation of data**

1.2.2.1 Writing of reports

Reports required will fall into one of the following classifications: (1) data report; (2) activity report; (3) special report; (4) annual progress report; (5) completion report; (6) report for publication.

Reports are frequently required from fish research personnel on unscheduled work. Investigations of diseased fish, brief studies of lakes or streams, and summaries of special data for administrative use are examples of reports that would fall in the special report category. The content of special reports should follow any convenient and logical form that best fits the individual situation.

Reports of trips should be written as soon as possible, while details are still fresh in the memory. A preliminary expedition report should be assembled for immediate discussion, and might take the following form.

A. Expedition plan

1. Copy of original plan.
2. Statement of departures from plan and reasons for these.

B. Work performed.

1. Summary tabulation of:

(*a*) area(s) worked
(*b*) station occupied
(*c*) operations carried out
(*d*) material collected

2. Statement of records kept (log identification numbers, etc.) and of where these are lodged.

C. Principal results, so far as these appear prior to detailed laboratory working up.

The preliminary results of investigations are more valuable if they are made available for distribution as soon as possible, especially if they are not only in the form of rough data but also contain comments and tentative conclusions.

Such a preliminary report would be only a working document for record and discussion purposes and for internal use. It should be followed by a report developed after material has been worked up, tabulated and placed on maps and diagrams. This second report, which can be for wider circulation, should be a self-contained account of the expedition, and preparation of it should not be made contingent in any way on completion of the research program of which the expedition was part. It should show:

Objectives
Area of operations and itinerary
Staff
Equipment and methods
Work done (stations occupied, operations carried out)
Materials collected
Results obtained

The following general guiding principles for the writing of reports are stressed at research institutions. Where applicable, these principles should be adhered to in preparing reports.

1. The introduction should make a favorable impression on the reader, leading him to read at least the summary.

2. The summary should be written in language meaningful to the top executive who may read it.

3. The summary should mention all important parts of the work, and every statement in the summary should be developed at greater length in the body of the report.

4. The introduction should tell (*a*) why the work was done, (*b*) when the work was done, (*c*) what the reader needs to know in order to understand the body of the report.

5. The various subdivisions of the body of the report should be arranged in logical order, and their relationship to one another and the body of the report made clear throughout.

6. The report should be positive in attitude, impersonal in style, and professionally dignified in manner.

7. The report should be made readable, by using short sentences, active verbs, and simple words in preference to complex.

8. The grammar should be acceptable without being artificial or stiff.

9. There should be just enough words, neither too few nor too many, with every word accurate and well chosen.

10. All tables and graphs should be arranged so that they may be reproduced without confusion and delay and the reader may understand them without special help.

1.2.2.2 Presentation of data

It is desirable to present as much data as possible in visual form (graphs, profiles, maps). The choice of map scale and projection depends on the subject and area of interest. In marine work usually mercator projections are used. In some work it is necessary to use not only the geographical positions, but in addition the Marsden squares.

This system was devised by Marsden in 1831. He divided a Mercator chart of the world into rectangles of 10° latitude by 10° longitude. Each rectangle is arbitrarily numbered and is again subdivided into 100 one-degree squares which are numbered from 00 to 99 so that, given the position of the squares, the first figure of the subsquare denotes the latitude and the second figure the longitude. (See Figure 1.) The one-degree squares are indicated in the accompanying diagram by dotted lines, which shows also how each Marsden square may be subdivided into 25 two-degree squares (light continuous lines) or 4 five-degree squares (bold continuous lines).

In quoting a reference number the digits standing for the Marsden square number are separated from those indicating a subdivision by a full point. If it is necessary to distinguish in the notation between one-degree and two-degree squares, it is suggested that in the latter case a hyphen be used instead of a point to separate the two parts of the number, thus: 62-06.

Before the expedition starts it is desirable to prepare scaled blank profiles for use on board and for the working up of data. As an example of profile scales, the following relation could be given:

(*a*) Surface profile 0 to 300 m

Scale: 10 sea miles = 2 mm

10 m depth = 4 mm

It is advisable to present the marine environmental data in data reports as soon as possible. The following set of data may serve as an example:

1. Profiles

Surface profiles:

(*a*) T °C (and thermocline)
S °/oo

(*b*) O_2
PO_4-P

(*c*) Chlorophyll μg/m³
Zooplankton biomass mg/m³

Surface to bottom profile:

(*a*) T °C
S °/oo

(*b*) O_2
PO_4-P

2. Tabulated data

(*a*) Tabulated hydrographical data
(*b*) Sighting of fish schools, birds, etc.
(*c*) Catches with fishing gear
(*d*) Benthos data

3. Track charts with notations of stations, surface temperatures, convergences, relative values of surface turbidity, etc.

Several biological data can be expressed in various ways. Figure 2 illustrates the effects of the different representation.

More detailed information on representation and working up of collected data will be found in other FAO publications and documents.

1.2.3 **Shipboard photography**

To give detailed instructions for photography would require a separate textbook. Reference is therefore made only to a few points concerning the use of photography at sea. It may be said that it is good practice to be liberal in the use of the camera during an expedition, since this may provide valuable records. Routine operations do not normally need to be

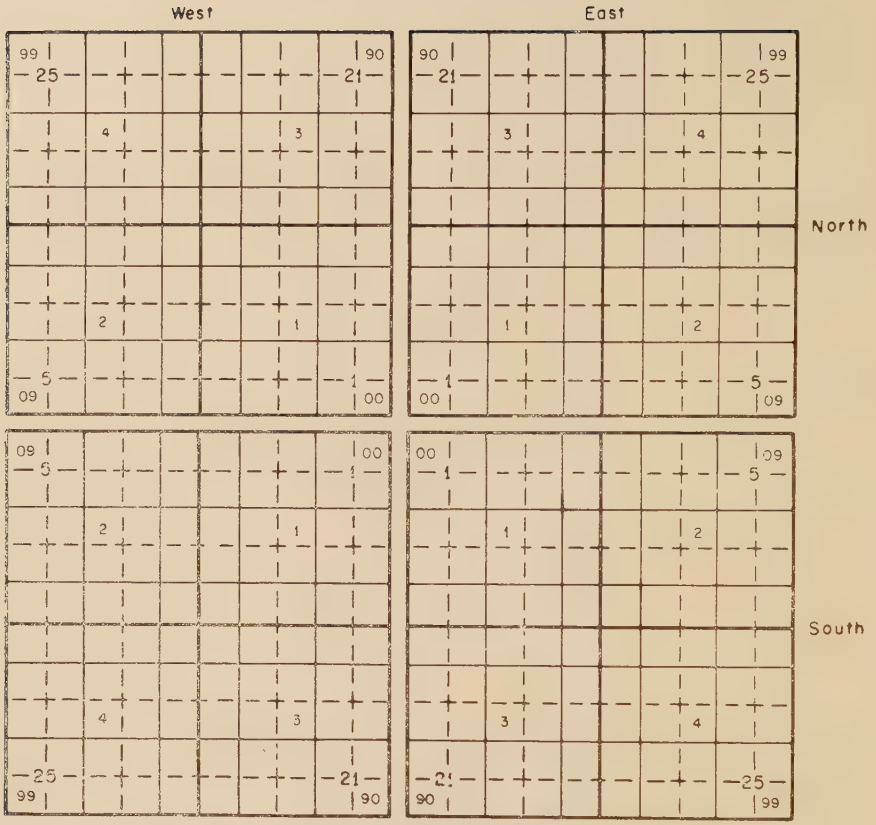

FIGURE 1. - Numbering of Marsden squares

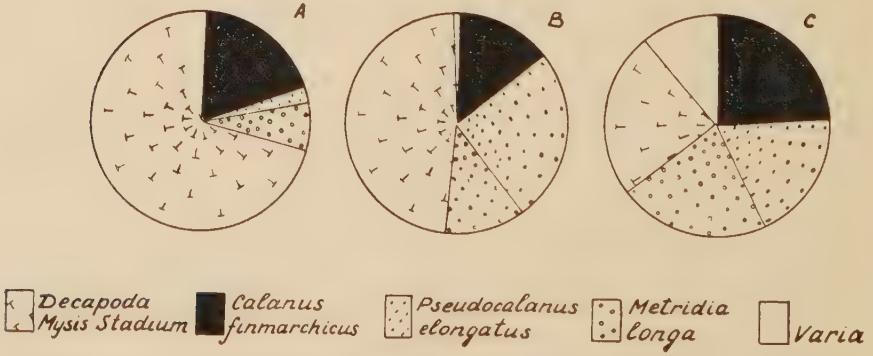

FIGURE 2. - The importance of different food components in the nutrition of the herring (from the White Sea) expressed in: A - weight, B - number of organisms, and C - frequency of occurrence (after Bogorov)

documented in this way, but special operations and particular phenomena such as discoloration of the sea, mass mortalities (most of which require color film) are most effectively reported with photographic evidence. Special studies, such as the schooling habits of pelagic fish, benefit greatly from a photographic record.

Photographs of matters of interest should always be taken at the first opportunity, not postponed in hope of the most favorable circumstances: they may not come. Whenever possible a photographic plan should be prepared beforehand; this is indispensable for a cinematographic record of operations. Special precautions must be taken to protect photographic equipment against the effects of salt spray. Exposed metal parts should be given a light coat of thin oil.

Exposures at sea generally require special care in light measuring. Reference should be made to photographic manuals for rules on this and on such matters as choice of film.

1.2.4 Selective list of manuals and textbooks in fisheries, oceanography and limnology

(*Note*: For specific detailed references see end of corresponding Sections)

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Barnes, H. 1959 *Apparatus and methods of oceanography*. Part I. *Chemical*. London, Allen and Unwin. 341 p.

Boudarel, N. 1948 *Les richesses de la mer: technologie biologique et océanographique*. Paris, Lechevalier. 549 p.

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Capurro, L. 1959 *Química del agua de mar*. Buenos Aires, Servicio de Hidrografía Naval. 140 p.

Davis, C.C. 1955 *The marine and freshwater plankton*. East Lansing, Michigan State University Press. 562 p.

De Buen, F. 1952 *Las familias de peces de importancia económica*. Santiago de Chile, FAO. 311 p.

Demel, K. & Kulikowski, J. 1955 *Oceanografia rybacka*. Warszawa, Panstwowe Wydawnictwo Naukowe. 283 p.

Dietrich, G. & Kalle, K. 1957 *Allgemeine Meereskunde*. Berlin, Borntraeger. 492 p.

Francis-Boeuf, C. 1947 *Les océans*. Paris, Presses universitaires de France. 128 p.

Grimpe, G. 1925-44 *Die Tierwelt der Nord- und Ostsee*. Leipzig, Akademische Verlags-Gesellschaft. 12 vols.

HUTCHINSON, G. E. *A treatise on limnology*. New York, Wiley. 1015 p.
1957

KUENEN, P. H. *Marine geology*. New York, Wiley. 568 p.
1950

LAFOND, N. C. *Processing oceanographic data*. Washington, D.C., U.S.
1951 Navy Hydrographic Office. 114 p. H.O. Pub. 614.

LAGLER, K. F. *Freshwater fishery biology*. Dubuque, Iowa, Brown. 421 p.
1956

LÜBBERT, H., EHRENBAUM, E. & WILLER, A., eds. *Handbuch der Seefischerei*
1928-58 *Nordeuropas*. Stuttgart, Schweizerbart. 22 vols.

MARR, J. C. *Biología pesquera marina*. Santiago de Chile, FAO. 143 p.
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MARTÍNEZ-HIDALGO Y TERÁN, J. M., ed. *Enciclopedia general del mar*. Ma-
1957-58 drid, Garriga. 6 vols.

NAINTRÉ, L. *Traité de la pêche en mer*. Paris, Crespin-Leblond. 349 p.
1960

PARDO, L. *Acuicultura continental*. Barcelona, Salvat. 443 p.
1951

ROMANOVSKY, V. *et al. La mer*. Paris, Larousse. 503 p.
1953

ROUCH, J.A.P. *Les océans*. Paris, Colin. 216 p.
1957

ROUNSEFELL, G. A. & EVERHART, W. H. *Fishery science: its methods and*
1953 *applications*. New York, Wiley. 444 p.

RUTTNER, F. *Grundriss der Limnologie* (*Hydrobiologie des Süsswassers*).
1962 3. neubearb. und erweiterte Aufl. Berlin, Gruyter. 332 p.

SCHOTT, G. *Geographie des Indischen und Stillen Ozeans*. Hamburg, Boysen.
1935 413 p., charts.

SCHOTT, G. *Geographie des Atlantischen Ozeans*. Hamburg, Boysen. 438 p.,
1942 charts.

STRICKLAND, J.D.H. & PARSONS, T. R. *A manual of sea water analysis*.
1961 Ottawa, Fisheries Research Board of Canada. 185 p. Bulletin 125.

SVERDRUP, H. U., JOHNSON M. W., & FLEMING, R. H. *The oceans: their*
1949 *physics, chemistry and general biology*. New York, Prentice-Hall.
1087 p.

THIENEMANN, A., ed. *Die Binnengewässer Mitteleuropas*. Stuttgart, Schweizer-
1925 bart. 255 p. Die Binnengewässer, Bd. 1.

U. S. NAVY HYDROGRAPHIC OFFICE. *Instruction manual for oceanographic*
1955 *observations*. 2nd ed. Washington, D.C. 210 p. H.O. Pub. No. 607.

VIBERT, R. & LAGLER, K. F. *Pêches continentales: biologie et aménagement*.
1961 Paris, Dunod. 720 p.

WELCH, P. S. *Limnology*. New York, McGraw-Hill. 471 p.
1935

YAÑEZ, P. *Introducción a la bibliografía pesquera*. Santiago de Chile, FAO.
1952 89 p.

ZOBELL, C. E. *Marine microbiology*. Waltham, Mass., Chronica Botanica.
1946 240 p.

Price: $0.50 or 2s 6d

15615/8.65/E/1/3800

FISH & WILDLIFE SERVICE

MANUAL OF METHODS IN FISHERIES BIOLOGY

compiled by

T. LAEVASTU

Fascicule 3

Section 2. Observations on the physical and chemical environment

2.0 Introduction
2.1 Fixing of position, bathymetry, bottom sampling

FOOD AND AGRICULTURE ORGANIZATION OF THE UNITED NATIONS
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SECTION 2. OBSERVATIONS ON THE PHYSICAL AND CHEMICAL ENVIRONMENT

2.0 INTRODUCTION

The observations for which techniques are described here are among the complementary observations discussed in Section 1.1. It is to be emphasized that the plan for observations of this kind is to be made in accordance with the over-all plan, for the research of which the field work is part; hence it must not be thought that all the techniques described here are to be used during each field trip.

2.1 FIXING OF POSITION, BATHYMETRY, BOTTOM SAMPLING

2.1.1 **Fixing and plotting of position**

The determination of the position of the station and the ship's route is usually done by navigation officers. In special cases, in research vessels and in smaller boats, some of this work, as well as plotting the fixes with given data, must also be done by the scientists on board. This they can do easily without much practice and knowledge in coastal waters and in lakes, but to fix a position in offshore waters considerable knowledge and practice in astronomical navigation is necessary.

The tracks of the research boats and the position of all fixes should be plotted on the navigation charts and/or on blotting sheets in duplicate. The position of the stations should be recorded in the logs by latitude, longitude, depth of water, and hour.

2.1.1.1 Sea charts

Sea charts are available in different scales at all port offices. It is advisable to keep a complete set of charts of the area concerned in the laboratory. These are on the Mercator projection, which is a "direction true" but not equal area or distance projection. The scale is marked on the margin in nautical miles. It varies with latitude, and is roughly independent of direction.

For numerical computation of distances and positions, the following simple formulas are used:

$b = d.\ \cos\ \alpha$

α = the angle between the course and longitude

d = distance traveled in sea miles

b = difference in latitude in sea miles

$a = d.\ \sin\ \alpha$

a = difference in longitude in sea miles

The conventional signs used on the sea charts are shown in Figure 1.

2.1.1.2 Terrestrial navigation and fixing of position

In terrestrial navigation (coastal navigation and navigation in lakes) use is made of visible fixes on the land and at the bottom of shallow water. A compass which is fitted with a special bearing arm and of which the rose is graduated in degrees, can be used for taking bearings. Certain corrections must sometimes be made to the readings before plotting. The different corrections to be considered are shown in Figure 2. Sextants and/or octants are used to measure horizontal and vertical angles at sea (Figure 3). Practice is necessary for handling and reading sextants.

(*a*) *One object in sight*

1. The bearing of the object is taken by compass and the position of the bearing line is roughly determined by sounding.
2. If a higher point (e.g., light, mountain, etc.) is in sight and its height is indicated on the chart, then the vertical angle between the top of the object and the sea level is measured with the sextant (Figure 4). The distance from the object is calculated as follows:

$$\text{L (distance in sea miles)} = \frac{13 \quad \text{H (in meters)}}{7 \quad \text{n (in number of arc minutes)}}$$

The bearing line is taken with the compass as for L.

(*b*) *Two objects in sight*

The bearings of both are taken by compass and marked on the map (Figure 5). The compass deviation and the deviation of magnetic *N* from true *N* must be taken into account. The angles should not be too sharp or too large.

(*c*) *Three objects in sight*

1. All three angle bearings are measured by compass and marked on the map.
2. The angles are measured by sextant. The point is marked on the map by double transporter. This last-mentioned method is the most accurate and should be used whenever possible (Figure 6).

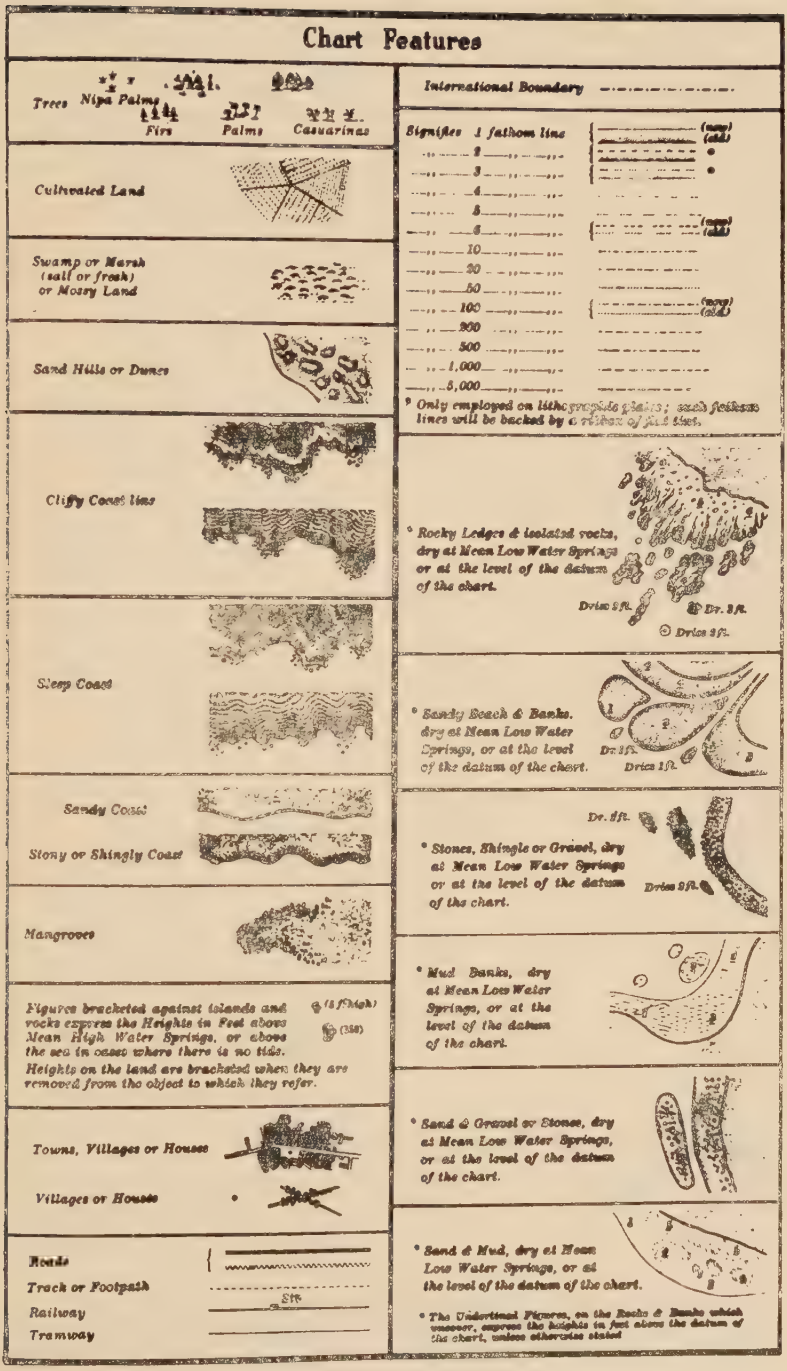
Chart Features
Trees
Nipa Palms
Firs
Palms
Casuarinas
Cultivated Land
Swamp or Marsh (salt or fresh) or Mossy Land
Sand Hills or Dunes
Cliffy Coast line
Sleep Coast
Sandy Coast
Stony or Shingly Coast
Mangroves
Figures bracketed against islands and rocks express the Heights in Feet above Mean High Water Springs, or above the sea in cases where there is no tide.
Heights on the land are bracketed when they are removed from the object to which they refer.
Towns, Villages or Houses
Villages or Houses
Roads
Track or Footpath
Railway
Tramway
International Boundary
Signifies 1 fathom line
2
3
4
5
6
10
20
50
100
200
500
1,000
5,000
Only employed on lithographic plates; such fathom lines will be backed by a ribbon of pale blue.
Rocky Ledges & isolated rocks, dry at Mean Low Water Springs or at the level of the datum of the chart.
Dries 3 ft.
Dr. 3 ft.
Dries 3 ft.
Sandy Beach & Banks, dry at Mean Low Water Springs, or at the level of the datum of the chart.
Dr. 1 ft.
Dries 1 ft.
Stones, Shingle or Gravel, dry at Mean Low Water Springs or at the level of the datum of the chart.
Dr. 1 ft.
Dries 3 ft.
Mud Banks, dry at Mean Low Water Springs, or at the level of the datum of the chart.
Sand & Gravel or Stones, dry at Mean Low Water Springs, or at the level of the datum of the chart.
Sand & Mud, dry at Mean Low Water Springs, or at the level of the datum of the chart.
The Underlined Figures, on the Rocks & Banks which uncover, express the heights in feet above the datum of the chart, unless otherwise stated

FIGURE 1. - Conventional signs used on charts

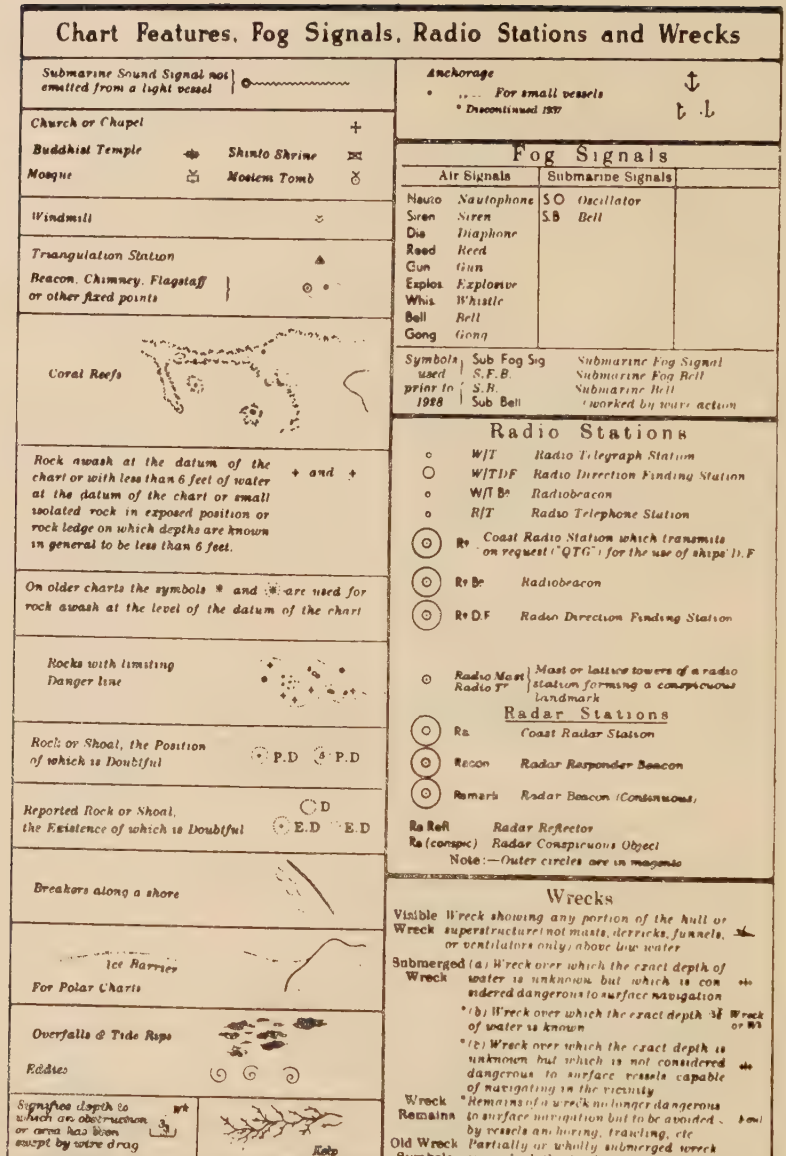
Chart Features, Fog Signals, Radio Stations and Wrecks
Submarine Sound Signal not emitted from a light vessel
Church or Chapel
Buddhist Temple
Shinto Shrine
Mosque
Moslem Tomb
Windmill
Triangulation Station
Beacon, Chimney, Flagstaff or other fixed points
Coral Reefs
Rock awash at the datum of the chart or with less than 6 feet of water at the datum of the chart or small isolated rock in exposed position or rock ledge on which depths are known in general to be less than 6 feet.
and
On older charts the symbols * and ⁂ are used for rock awash at the level of the datum of the chart
Rocks with limiting Danger line
Rock or Shoal, the Position of which is Doubtful
P.D
P.D
Reported Rock or Shoal, the Existence of which is Doubtful
D
E.D
E.D
Breakers along a shore
Ice Barrier
For Polar Charts
Overfalls & Tide Rips
Eddies
Signifies depth to which an obstruction or area has been swept by wire drag
Kelp
Signifies no bottom found at the depth expressed
10
100
Fishing Stakes
Submarine Cable
Power Cable
Power
The word "Overhead" and the height in feet above H.W. are added where necessary on the largest scale charts.
Anchorage
For small vessels
Discontinued 1937
Fog Signals
Air Signals
Submarine Signals
Nauto Nautophone
Siren Siren
Dia Diaphone
Reed Reed
Gun Gun
Explos Explosive
Whis Whistle
Bell Bell
Gong Gong
S.O Oscillator
S.B Bell
Symbols used prior to 1928
Sub Fog Sig Submarine Fog Signal
S.F.B. Submarine Fog Bell
S.B. Submarine Bell
(worked by water action)
Radio Stations
W/T Radio Telegraph Station
W/T D/F Radio Direction Finding Station
W/T Bn Radiobeacon
R/T Radio Telephone Station
Rn Coast Radio Station which transmits on request ("QTG") for the use of ships D.F
Rn Bn Radiobeacon
Rn D.F Radio Direction Finding Station
Radio Mast / Radio Tr Mast or lattice towers of a radio station forming a conspicuous landmark
Radar Stations
Ra Coast Radar Station
Racon Radar Responder Beacon
Ramark Radar Beacon (Continuous)
Ra Ref Radar Reflector
Ra (conspic) Radar Conspicuous Object
Note:—Outer circles are in magenta
Wrecks
Visible Wreck showing any portion of the hull or superstructure (not masts, derricks, funnels, or ventilators only) above low water
Submerged Wreck (a) Wreck over which the exact depth of water is unknown but which is considered dangerous to surface navigation
*(b) Wreck over which the exact depth of water is known
*(c) Wreck over which the exact depth is unknown but which is not considered dangerous to surface vessels capable of navigating in the vicinity
Wreck Remains *Remains of a wreck no longer dangerous to surface navigation but to be avoided by vessels anchoring, trawling, etc
Old Wreck Symbols Partially or wholly submerged wreck over which the depth is unknown
Note —On large scale plans, on which the wrecks are frequently delineated in outline, visible wrecks (as defined above) are shown in firm outline, and submerged wrecks in pecked outline, such outlines being marked "Wreck"
In the case of submerged wrecks whether delineated in outline, or shown by a symbol, where it is known that masts and/or funnels are visible a note to that effect may be inserted, e.g.
Wreck (Mast 5 feet / Funnel / Mast, about 2 feet)
Masts and funnel
*Where the depth over a wreck exceeds 6 fathoms or a wreck is considered non-dangerous the corresponding symbol is sometimes given on the largest scale charts only

FIGURE 1 (cont.) - Conventional signs used on charts

Tides and Tidal Streams

M.H.W.S. ..... Mean High Water Springs
M.H.W.N. ..... " " " " Neaps
M.L.W.S. ..... Mean Low Water Springs
M.L.W.N. ..... " " " " Neaps
} Mean Heights where tide is semidiurnal

M.H.H.W. ..... Mean Higher High Water
M.L.H.W. ..... " Lower " " "
M.L.L.W. ..... Mean Lower Low Water
M.H.L.W. ..... " Higher " " "
} Average daily heights where the diurnal inequality is large or the tide is diurnal.

Fl., fl. ..... Flood
H.W. ..... High Water
h. ..... hour hours
kn. ..... knot, knots
L.W. ..... Low Water
I.S.L.W. ..... Indian Spring Low Water
* For definition see Admiralty Tide Tables, Part III.
M.T.L. ..... Mean Tide Level

m. ..... minutes
Np. ..... Neap Tides
Qr ..... Quarter
Sp., Spr. ..... Spring Tides
§ ..... Current
..... Flood Stream
..... Ebb "
M.S.L. ..... Mean Sea Level

etc. Chart gives information regarding the Tidal Streams at the pos[n] occupied by these symbols.

† The period of the tide at which the streams are running in the direction of the arrows is denoted as follows:-
① 1st Qr, 2nd Qr, etc. for the Quarters of each Tide ..... 2nd Qr 2nd Qr
② Ih IIh IIIh etc. for 1st 2nd 3rd hours after High or Low Water.. IIh IIIh
③ Black dots on the arrows, the number of hours after High or Low Water

§ The Rate of Currents and Tidal Streams is expressed in knots, thus:— 1kn 3kn

1* The use of these terms is being discontinued.

Buoys and Beacons

Light Buoys
Gong Buoys — Gong Gong Gong
* Bell Buoys — Bell Bell Bell; Symbol prior to 1942
* Can Buoys — B W R Bl; B.W B.W B.W
* Conical Buoys — B W R G; B.W B.W B.W Y
* Spherical Buoys — B.W W

Buoys with Topmarks
Spar Buoys, Pillar Buoy
Mooring Buoys
Fixed or Floating Beacons — (Lazy Vee)
Light Vessels or Floats

The Position of a Light Vessel, Buoy or Beacon is the Centre of the Base, and is usually indicated by a small circle

B., Blk.... Black
Cheq .... Chequered
G. ..... Green
Gy ..... Gray
H.S.... Horizontal Stripes
No. ..... Number
Refl. ..... Reflector
R. ..... Red
Bl. ..... Blue
V.S. ..... Vertical Stripes
Y. ..... Yellow
W., Wh.... White

The Heights given against Beacons and marks thus:— • 8m (35) • Ch7 (15m) represent the Height of the Top of the object above Mean High Water Spring Tides, or above the Sea level where there is no tide

Colours of Buoys are shown in alphabetical order.
† For Automatic Bell Buoys period & number of strokes shown thus:— Bell (2) 90 sec
* In the case of two-colour buoys each colour is indicated below the appropriate symbol.
On certain older charts the symbols H.S., V.S., & Cheq. appear in addition.

FIGURE 1 (cont.) - Conventional signs used on charts

Lights

★ * .....*Lights, Position of*

La, La.....*Light, Lights*

† La Alt. .....Alt.....*Light Alternating*

La F. .....F..... „ ...*Fixed*

La Fl.....Fl..... „ ...*Flashing*

La Occ. .....Occ. ..... „ ...*Occulting*

Fl. (S-L) „ *Flashing (Short and Long flashes)*

La F. Fl.....F. Fl. ..... „ ...*Fixed & Flashing*

° La Gp. Fl. (3).....Gp. Fl. (3)..... „ ...*Group Flashing*

° La F. Gp. Fl. (4).....F. Gp. Fl. (4)..... „ ...*Fixed & Group Flashing*

° La Gp. Occ. (2)...Gp. Occ. (2)..... „ ...*Group Occulting*

Gp. Fl. (S-L) „ *Group Flashing (Short and Long flashes)*

° Air Gp. Fl. (AB) „ *Air Light Flashing – – –*

Qk. Fl.....e..*Quick Flashing*

Int. Qk. Fl. ... *Interrupted Quick Flashing*

Gp. Int. Qk. Fl.. *Group Interrupted Quick Flashing*

† *Alt*.....*alternating*

fl. fl.....*flash, flashes*

Gp.....*Group*

hori.....*horizontal* (*Lights placed horizontally*)

irreg. .....*irregular*

m .....*M*.....*miles*

min. .....*minute or minutes*

obscd.....*obscured*

‡ *occasl* .....*occasional*

sec. .....*second or seconds*

(U) .....*Unwatched*

vertl.....*vertical* (*Lights placed vertically*)

vis. .....*visible (now obsolete)*

Colours of lights

.....Bl.....*Blue* ...Vi...*Violet or Purple*

G., Gn ...G. .....*Green* W., Wh...W...*White*

.....Or.....*Orange, Yellow or Amber*

R. .....R. .....*Red*

★ Gp Occ. (2) W.R. 5 sec. 130 ft. 12 M. (U).....*Example of full abridged description of light.*

† Alt. (*Alternating*) *signifies a Light which alters in colour.*

° *The number in brackets after the description of Group Flashing or Group Occulting Lights, denotes the number of flashes or eclipses in each group. The characteristics of Air Lights which exhibit groups of flashes representing letters of the Morse Code are shown by the appropriate letters in brackets.*

‡ *Occasional Light or Fog Signal is a signal which is only given when a vessel is expected or in answer to vessels signals or at other irregular times.*

The height given against a light is the height of the focal plane of the light above Mean High Water Spring Tides, or above the Sea level in cases where there is no tide.

The visibility of lights is given in nautical miles, assuming the eye of the observer to be 15 feet above the sea.

Bearings of Lights are given from Seaward.

General Remarks

MERIDIANS. *Charts are generally drawn on the True Meridian; if otherwise, a True Meridian is given on the chart.*

LONGITUDES. *All Longitudes are referred to the Meridian of Greenwich.*

SOUNDINGS. *Soundings are expressed in Feet or Fathoms, as stated in the title of the chart.*
1 Fathom = 6 Feet = 1·828798 Metres.

On charts published after 1922 soundings of under 11 fathoms (20m 1) are shown in fathoms and feet, instead of in fathoms and fractions of a fathom thus:—
The sounding 8₅ represents a depth of 8 fathoms 5 feet (16m 2).
„ „ 0₃ „ „ „ „ 0 fathoms 3 feet (0m 9).
The centre of the space occupied is the position of the depth indicated.

DRYING HEIGHTS. *Underlined Figures, on Rocks and Banks which uncover, express the Heights in Feet above the Datum of the Chart, unless otherwise stated.*

HEIGHTS. *All Heights (except those expressed in underlined figures as above) are, unless otherwise stated, given in Feet above Mean High Water Springs, or, in places where there is no tide, above the Level of the Sea.*

SCALES. *The Natural Scale is the proportion which any measurement on the chart bears to the actual distances represented, and is shown thus:—* $\frac{1}{120,000}$
A Sea Mile is the length of a minute of Latitude at the place, and a Cable is assumed to be a tenth part of a Sea Mile.

DIMENSIONS OF PLATE. *The Figures in Brackets in the bottom right-hand corner of a chart, thus:—(30·4 x 25·0) are the dimensions of the plate in Inches between the innermost graduation or border lines.*

DATES OF CHART CORRECTIONS. *For the method of dating charts for corrections see Introductory chapter in Admiralty Sailing Directions.*

NAMES. *Alternative names are indicated by the use of the word "or". Names shown in brackets are generally obsolete names to read with the Admiralty S.D. of an earlier date, but occasionally they are correctional names or new names.*

FIGURE 1 (concl.) - Conventional signs used on charts

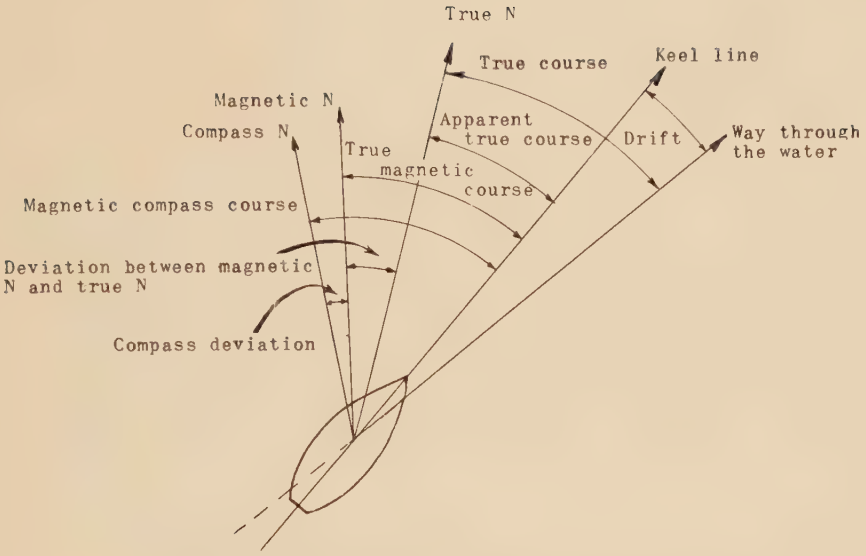

FIGURE 2. - Determination of true course of a ship

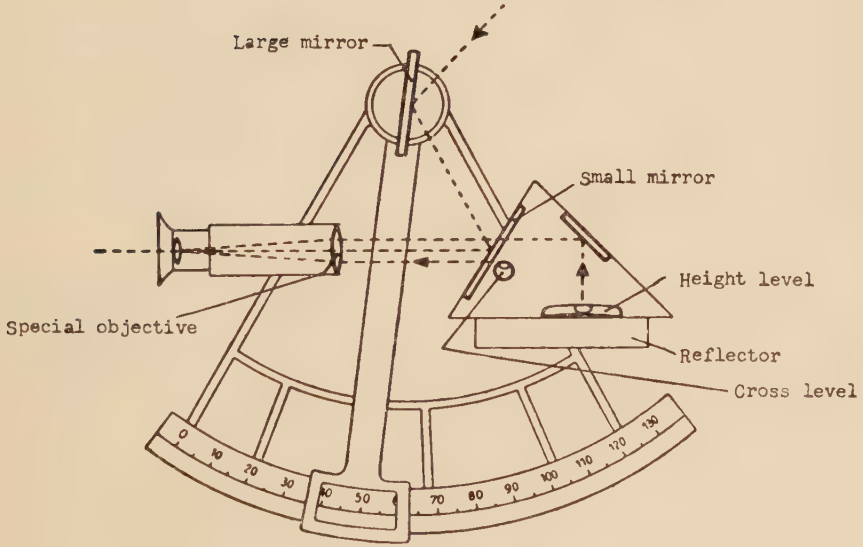

FIGURE 3. - Sextant elements

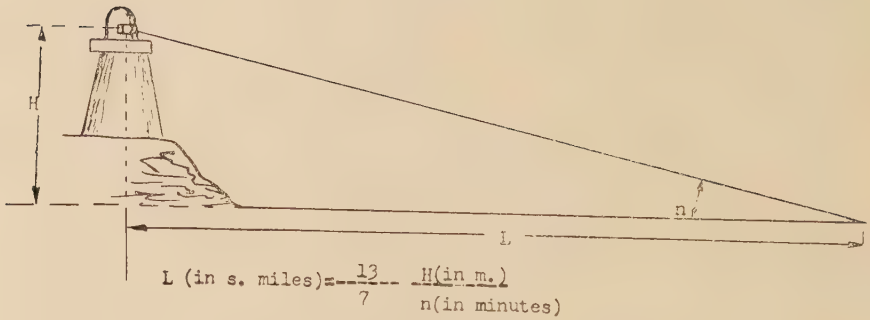

FIGURE 4. - Determination of position with one object in sight

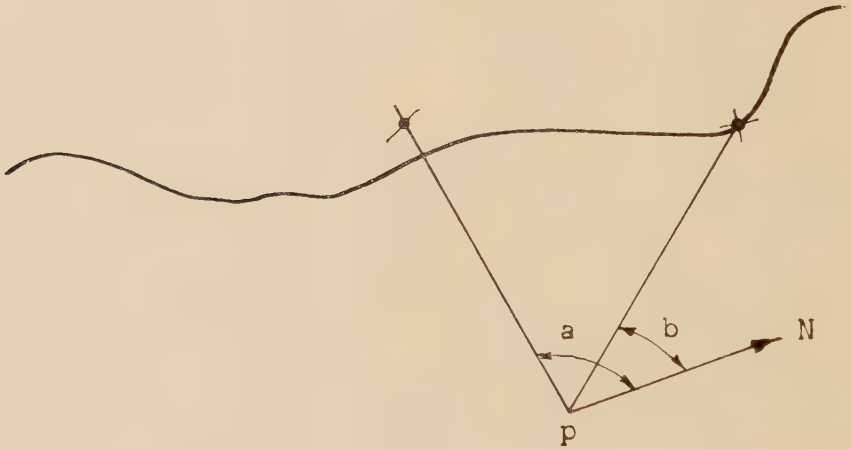

FIGURE 5. - Determination of position with two objects in sight

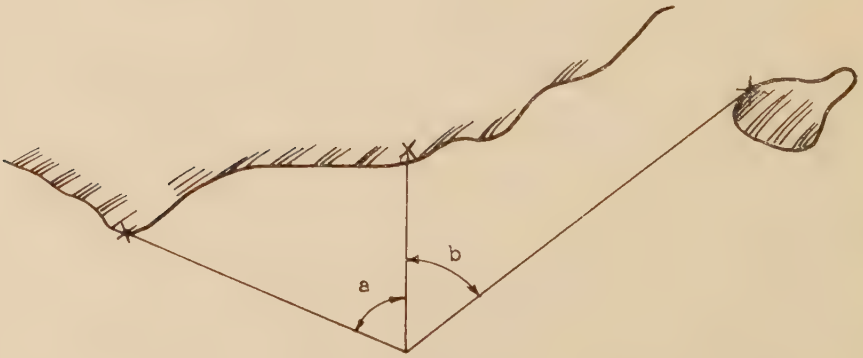

FIGURE 6. - Determination of position with three objects in sight

2.1.2 Sounding

When soundings are made, especially in shallow water, the state of the tides must be considered or the time of sounding noted so that tide correction can be made in referring the depth to a standard tide level.

2.1.2.1 Sounding with lead and line

Sounding with lead and line is done only in very shallow water. The line must be marked in meters or in fathoms and feet. These calibrations must be checked for accuracy after the line has been wetted and stretched. Table 1 gives fathom and meter equivalents. Care must be taken that the line is not at a great angle when taking depth soundings and that the cable tension is correct. If the lead has a short tube fitted with a top valve, a small sediment sample can be obtained when sounding, and information obtained about the nature of the sea bottom.

2.1.2.2 Sounding by pressure

This method has the advantage that soundings can be made while under way. The most commonly used pressure instrument is the Thompson sounder. The basis of the Thompson sounder is a vertical glass tube about 610 mm long, closed at the top and coated inside with silver chromate which changes in color from red to gray-yellow on contact with sea water. The deeper the tube sinks the greater the pressure and the higher the water rises in the tube against the contained air. The length of silver chromate wetted gives a measure of the pressure and therefore of the depth. Table 2 shows the conversion factors. Before use, the tubes should be brought approximately to the same temperature as the bottom water. When taken out from the holder after arriving on board, the tubes should be kept in a vertical position. The conversion of fathoms to meters is given in Table 1.

2.1.2.3 Other sounders

Several sounders use explosives which detonate on hitting the sea bottom, but they are rather expensive and usually need a special listening apparatus. The time taken to reach the bottom, sinking velocity being constant, indicates the depth.

2.1.2.4 Echo-sounders

Echo-sounders (Figure 7) are among the most essential instruments in present day fisheries research. They are used not only for determination of depth,

TABLE 1. - DEPTH CONVERSION - FATHOMS TO METERS

Fathoms	0	1	2	3	4	5	6	7	8	9
0	0.0	1.8	3.7	5.5	7.3	9.1	11.0	12.8	14.6	16.5
10	18.3	20.1	21.9	23.8	25.6	27.4	29.3	31.1	32.9	34.7
20	36.6	38.4	40.2	42.1	43.9	45.7	47.5	49.4	51.2	53.0
30	54.9	56.7	58.5	60.3	62.2	64.0	65.8	67.7	69.5	71.3
40	73.2	75.0	76.8	78.6	80.5	82.3	84.1	86.0	87.8	89.6
50	91.4	93.3	95.1	96.9	98.8	100.6	102.4	104.2	106.1	107.9
60	109.7	111.6	113.4	115.2	117.0	118.9	120.7	122.5	124.4	126.2
70	128.0	129.8	131.7	133.5	135.3	137.2	139.0	140.8	142.6	144.5
80	146.3	148.1	150.0	151.8	153.6	155.4	157.3	159.1	160.9	162.8
90	164.6	166.4	168.2	170.1	171.9	173.7	175.6	177.4	179.2	181.0
100	182.9	184.7	186.5	118.4	190.2	192.0	193.8	195.7	197.5	199.3
110	201.2	203.0	204.8	206.7	208.5	210.3	212.1	214.0	215.8	217.6
120	219.5	221.3	223.1	224.9	226.9	228.6	230.4	232.3	234.1	235.9
130	237.7	239.6	241.4	243.2	245.1	246.9	248.7	250.5	252.4	254.2
140	256.0	257.9	259.7	261.5	263.3	265.2	267.0	268.8	270.7	272.5
150	274.3	276.1	278.0	279.8	281.6	283.5	285.3	287.1	288.9	290.8
160	292.6	294.4	296.3	298.1	299.0	301.7	303.6	305.4	307.2	309.1
170	310.9	312.7	314.5	316.4	318.2	320.0	321.9	323.7	325.5	327.3
180	329.2	331.0	332.8	334.7	336.5	338.3	340.2	342.0	343.8	345.6
190	347.5	349.3	351.1	353.0	354.8	356.6	358.4	360.3	362.1	363.9
200	365.8	367.6	369.4	371.2	373.1	374.9	376.7	378.6	380.4	382.2
210	384.0	385.9	387.7	389.5	391.4	395.0	395.8	396.8	398.7	400.5
220	402.3	404.2	406.0	407.8	409.6	411.5	413.3	415.1	417.0	418.8
230	420.6	422.4	424.3	426.1	427.9	429.8	431.6	433.6	435.2	437.1
240	438.9	440.7	442.6	444.4	446.2	448.0	449.9	451.7	453.5	455.4

250	457.2	459.0	460.1	462.7	464.5	466.3	468.2	470.0	471.8	473.7
260	475.5	477.3	479.1	481.0	482.7	484.6	486.5	488.3	490.1	491.9
270	493.8	495.6	497.4	499.3	501.1	502.9	504.7	506.6	508.4	510.2
280	512.1	513.9	515.7	517.5	519.4	521.2	523.0	524.9	527.7	528.5
290	530.3	532.2	534.0	535.8	537.7	539.5	541.3	543.1	545.0	546.8

Fathoms	0	10	20	30	40	50	60	70	80	90
300	549	567	585	603	622	640	658	677	695	713
400	732	750	768	786	805	823	841	860	878	896
500	914	933	951	969	988	1,006	1,024	1,042	1,061	1,079
600	1,097	1,116	1,134	1,152	1,170	1,189	1,207	1,225	1,244	1,262
700	1,280	1,298	1,317	1,335	1,353	1,372	1,390	1,408	1,426	1,445
800	1,463	1,481	1,500	1,518	1,536	1,554	1,573	1,591	1,609	1,628
900	1,646	1,664	1,682	1,701	1,719	1,737	1,756	1,774	1,792	1,810

Fathoms	0	100	200	300	400	500	600	700	800	900
1,000	1,829	2,012	2,195	2,377	2,560	2,743	2,926	3,109	3,292	3,475
2,000	3,658	3,840	4,023	4,206	4,389	4,572	4,755	4,938	5,121	5,303
3,000	5,486	5,669	5,852	6,035	6,218	6,401	6,584	6,766	6,949	7,132
4,000	7,315	7,498	7,681	7,864	8,047	8,229	8,412	8,595	8,778	8,961
5,000	9,144	9,327	9,510	9,692	9,875	10,058	10,241	10,424	10,607	10,790
6,000	10,973	11,155	11,338	11,521	11,704	11,887	12,070	12,253	12,436	12,618
7,000	12,801	12,984	13,167	13,350	13,533	13,716	13,899	14,082	14,264	14,447
8,000	14,630	14,813	14,996	15,179	15,362	15,545	15,727	15,910	16,093	16,276
9,000	16,459	16,642	16,825	17,008	17,190	17,373	17,556	17,339	17,922	18,105

in trawling operations, but are also used for the scouting of fish schools. They can even be used for the determination of concentration of plankton and for a variety of other purposes. Besides vertical types, horizontal types, the so-called fish lupes, are available and are specially adapted for fish searching. Detailed descriptions of echo-sounders and asdic for fishing purposes can be found in references at the end of this Section. The operation of the units is described in manuals issued by the manufacturers; their maintenance is a specialist task beyond the responsibility of fishery field officers.

TABLE 2. - THE THOMPSON SOUNDER

Red part, in mm	Depth in m	Red part, in mm	Depth in m
296	10	120	42
284	11	116	44
273	12	112	46
262	13	103	48
253	14	104	50
244	15	101	52
235	16	98	54
227	17	95	56
220	18	92	58
213	19	90	60
207	20	84	65
194	22	79	70
183	24	74	75
173	26	70	80
164	28	66	85
156	30	63	90
149	32	60	95
142	34	57	100
136	36	55	105
130	38		
125	40		

2.1.3 **Bottom sampling**

Investigations on marine sediments often require bottom samples larger than those taken when sounding. There are several types of bottom sampler, depending on the kind of sample required and on the depth of water and nature of the sediment. No satisfactory sampler exists for use on hard bottoms. Taking and processing samples for benthos analysis is described in Section 3.3.

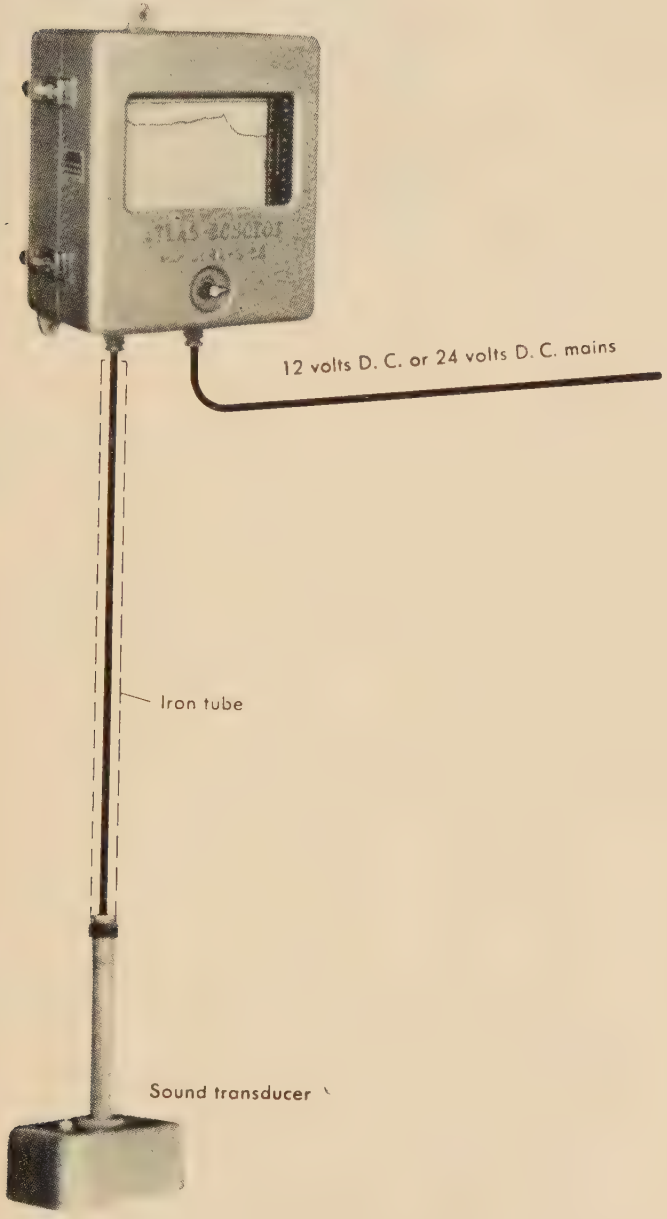

FIGURE 7. - Atlas echo-sounder, Monograph 58

Sediment samples are usually preserved in glass jars (1/4 to 1/2 liter) well corked and labeled.

Spring-loaded grabs and orange-peel samplers for sampling the sediment surface are commonly used (Figure 8). For taking short sediment cores there are various gravity corers (Figure 9), the effective tube length being usually 60-100 cm. These have removable liners, of cellophane or plastic, in which the samples can be preserved by corking at both ends. The tubes should be properly labeled, preferably with pens specially designed for the purpose. Paper labels are not good for use at sea because they easily become wetted and lost. Care must be taken that the valves and core catchers work properly. To obtain the maximum length of core the weight of the sampler and the lowering and hauling speeds must be adjusted to suit the nature of the sediment. There are several types of Kullenberg corers (piston corers) for taking long cores. The handling of these instruments needs special care and practice which varies according to the type used.

The codes and symbols given in Table 3 are suggested for use in recording the nature of the bottom substrata (type, consistency, color) in logs or on charts.

In stream surveys, bottom types will be described for pools and riffle areas in the section studied. Record the estimated percentages as called for on the record form. If bottom types are not recorded on the map of the lake, again standard techniques will be used.

The types of bottom soils are defined as follows:

Marl. Deposit of calcium carbonate. It may be concretion marl, shell marl (abundance of shells and shell fragments) or amorphous marl (uniform, relatively pure marl which clouds the water when disturbed).

Mud. A more or less compact mixture of clay and other soils.

Silt. A soft, flocculent, finely-divided soil.

Clay. A dense, compact, sticky and smooth soil. When dry it forms a hard clod difficult to break. When moist it is sticky and plastic, and when squeezed it does not crumble but works into a heavy, compact mass.

Sand. Loose, single-grained soils, gritty. Individual grains can be felt and seen.

Detritus. Composed of more or less finely-divided organic material, such as bits of leaves, twigs, bark, remains of water plants, etc. It is frequently found on the pool bottoms, or in the shelter of any obstruction to the current in streams.

Muck. Black, completely decomposed organic material.

Peat. Brownish to greenish, partly decomposed plant remains. It may be in the form of fibrous peat (coarser, herbaceous material, parts of plants relatively easily distinguished) or as pulpy peat (uniform fine texture, parts of plants not distinguishable).

Hardpan. Consists of hard deposit of clay which has been exposed by water action.

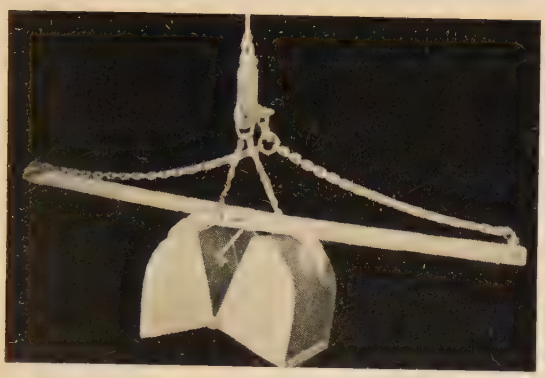

FIGURE 8. - Bottom grab
(Courtesy Laboratoire oceanog.,
Charlottenlund, Denmark)

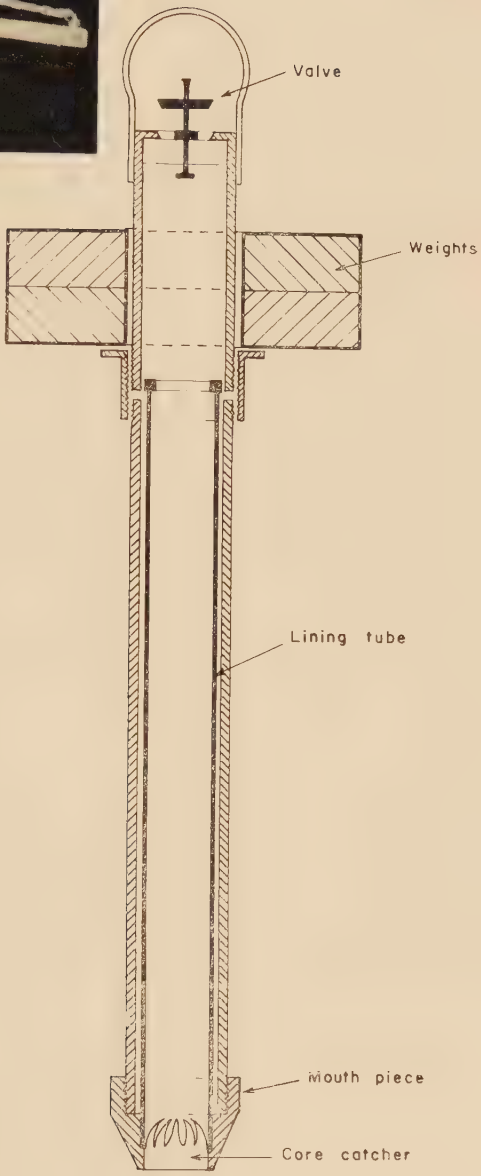

FIGURE 9. - Gravity corer

TABLE 3. - NOTATIONS FOR THE NATURE OF THE BOTTOM

Blue	b.	Mud	M.
Black	bl.	Mussels	Ms.
Brown	br.	Ooze	Oz.
Coarse	c.	Pebbles	P.
Calcareous	ca.	Pteropod	pt.
Chalk	Ck.	Pumice	Pm.
Clay	Cy.	Quartz	Qz.
Coral	Co.	Rock	R.
Dark	d.	Radiolaria	Rd.
Diatom	Di.	Red	rd.
Fine	f.	Sand	S.
Foraminifera	Fr.	Soft	so.
Gravel	Gr.	Shells	Sh.
Green	gn.	Small	sm.
Ground	Gn.	Stone	St.
Gray	gy.	Stiff	sf.
Glacial	ga.	Sticky	sy.
Hard	h.	Volcanic	v.
Large	l.	White	w.
Lava	Lv.	Weed	Wd.
Light	Lt.	Yellow	y.

Gravel. Individual particles ranging in size from about 2 mm to about 50 mm.

Rubble. Individual stones from 50 mm in size up to about 300 mm.

Boulder. Each stone above 300 mm in diameter.

Bedrock. Solid underlying layer of stone.

2.1.4 Analysis of bottom samples

It is often necessary determine the characteristics of the bottom, e.g., for finding out the preferred types of bottom in the spawning areas, for estimation of the available fish food on the bottom, using previously known relations between the type of bottom and the benthos communities and their standing crops, and in certain cases to estimate the conditions of the life of demersal fish in respect to the bottom substrata. Among the physical characteristics of the sediment, the grain-size distribution is one of the most important. As most of the bottom samples with which fisheries research is concerned are generally from the continental shelf and slope, or from lakes and streams, sieving techniques combined with gravimetric determination of the fractions is sufficient. In coagulated sediments it is sometimes necessary to use a dispersing agent before sieving a sample.

Of chemical analyses, the most important from a fisheries point of view are the determination of the organic matter and of carbonates. The simplest and best method for determination of the organic matter in sediments is the Shollenberg method with Allison's modifications lately described by S.K. El Wakeel and J. P. Riley (1957). For the determination of organic matter the ashing method can also be used, but is, however, considerably less accurate, especially when much fine clay and carbonates are present. For determination of the carbonates simple acid digestion methods can be used. A small sample will be well ground, set with a known volume and with known normality hydrochloric acid which is later titrated back with standardized alkali.

2.1.5 Determination of pool and shelter area in streams

In some stream studies it is desirable to know the amount of the stream bed in pools and in riffles. This may be done by measuring off about 100 meters of the stream and studying the pools and riffles according to size, type and frequency. Determine which of the following conditions most nearly applies to the pools found in the section and record data on the record form, using the symbols presented after the following description of conditions.

Size

1. Pools having an average width or length much greater than the width of the stream.
2. Width and length equal to width of the stream.
3. Much narrower or shorter than the stream width.

TYPE

1. Deep (2/3 meter or more), exposed pools containing a great amount of aquatic plants harboring a rich fauna; or deep pools with abundant shelter (overhanging banks, logs, roots, boulders), much drift and detritus shaded by forest cover or shrubs.
2. Pools intermediate in depth, shelter, plant abundance, etc.
3. Shallow exposed pools without shelter or plants, scoured basins.

FREQUENCY

1. More or less continuous pools - about 75 percent to 25 percent relation of pools and riffle areas.
2. Rather close succession of pools and rapids - 50-50 percent.
3. Pools infrequent with long stretches of swift, shallow water between, pools making up less than 25 percent of the total stream area.

In recording information use S for size, T for type and F for frequency. Thus the highest rating for a stream would be S - 1, T - 1, F - 1. The poorest rating would be S - 3, T - 3, F - 3.

The factors responsible for the pools at each station should also be listed, i.e., whether caused by boulders, logs, undercut banks, or simply by the cutting action of the streams. Under shelter, indicate the abundance of water plants, rocks, sunken logs, or whatever form of protection for fish is afforded by the pool.

2.1.6 Explanation of terms

ACID DIGESTION. Dissolving of materials soluble in acid(s).

BATHYMETRY. Measurement of the depth at which the bottom and objects on it lie below the surface.

BEARING. The direction in which an object, or position, lies from an observer.

COMPASS NORTH. The direction of north, indicated by compass (see Figure 4).

DEVIATION (NAVIGATIONAL). An unjustified and unnecessary departure from normal course or customary route.

DEVIATION (OF COMPASS). The angle that a compass needle makes with the magnetic meridian, due to magnetic forces in the ship or cargo.

DIATOM. Small (often microscopic) plant (algae), freely floating in sea water. Has small siliceous shells which after deposition can form diatom ooze.

DISPERSING AGENT. A chemical which helps the dispersing of sediment conglomerates (e.g., oxygen peroxide, sodium pyrophosphate, etc.).

DOUBLE TRANSPORTER. An instrument used for plotting positions.

ECHO-SOUNDER. An electrically operated instrument that emits a sound from a vessel's submerged surface and then measures the time interval until the return of the echo, and converts this time in-

terval into an estimate of the distance between the emitter and the object by which the sound has been reflected.

Fix. The position of a ship when found by the intersection of two or more position lines.

Foraminifera. Very small elementary animals which live in small calcareous shell, formed by themselves. If these shells are deposited on the sea floor in large amounts they form foraminifera ooze (also called globigerina ooze).

Gravel. Mineral particles 2-4 mm in diameter.

Magnetic north. The direction shown by the north-seeking pole of a compass needle.

Octant. Reflecting instrument for optical measurement of angles with an area of 45° and graduated to 90°.

Pebbles. Mineral particles (stones) with a diameter of 4-64 mm.

Pteropod. Small planktonic gastropod mollusks.

Quartz. A form of silica (SiO_2), usually colorless and transparent.

Radiolarian. A minute marine rhizopod having a siliceous skeleton.

Sand. Mineral particles with a diameter of 1/16-2 mm.

Sextant. Reflecting instrument used for measuring altitude and other angles not exceeding 120°.

Standardized alkali. An alkali solution with known strength (normality).

Titration. A method or process to determine the strength of a solution or the concentration of a substance in solution, in terms of the smallest amount of it required to bring about a given effect in reaction with another known solution or substance.

True north. Direction to the true, or geographical North Pole.

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T. LAEVASTU

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Section 2. Observations on the physical and chemical environment

2.2 Meteorological observations

FOOD AND AGRICULTURE ORGANIZATION OF THE UNITED NATIONS
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2.2 METEOROLOGICAL OBSERVATIONS

Meteorological observations should be made during field work in fisheries biology because of the direct and indirect influences exerted by meteorological elements on fish stocks. The state of the weather at a particular time exercises a considerable influence on the behavior of pelagic stocks in surface waters at that time. The amount of daylight in each 24 hours plays a considerable part in determining the level of basic production by phytoflankton. The effect of winds in causing water movements is a primary pactor in the determination of the distribution of nutrient salts.

Records of weather conditions are therefore necessary to the biologist directly, and are indirectly necessary from the use that can be made of them by the oceanographers. Detailed instructions on meteorological observational practices are laid down in WMO Pub. No. 8, especially in Chapter 10. Port meteorological officers in larger ports have further local information, and can check instruments and issue meteorological logbooks. It is in the interest of every observer to make himself familiar with the use and care of his instruments before undertaking routine observations.

Meteorological readings are recorded on an appropriate data sheet (Form 1). When working in small boats near the coast and/or lacking some instruments, short log sheets are used, omitting some data. Only the values obtained during the moment of observation or measurement should be recorded; such values generally have a close relation with the average values for an hour or more preceding the moment when they are taken. Some rules are provided in weather manuals to guide the choice of times and circumstances of meteorological observations, so that these should have maximum representativeness.

Synoptic meteorological observations should be taken at established standard hours (0000, 0600, 1200 and 1800, with intermediate observations at 0300, 0900 and 1500 GMT). Observations for special purposes can be taken at any time and can be recorded in the local time.

2.2.1 Wind

2.2.1.1 Direction

Wind direction offshore can be ascertained by observing the motion of true wind waves and ripples, but not of swell waves since these are caused by wind in some distant area. This method is inaccurate for positions close to the shore, because of shelter effects and the reflection of waves; other means must be used, such as observation of the movement of flags, smoke, etc.

Wind direction should be recorded in tens of degrees from true North (01-36).

2.2.1.2 Force (speed)

Wind speed is recorded by reference to the Beaufort scale in conjunction with Captain Petersen's sea and coastal criterion tables (Tables 1 and 2), or is measured with anemometers. When anemometer observations are taken

FORM 1. - METEOROLOGICAL DATA SHEET (AND BT DATA)

(*a*) Anemometer height — (*b*) Thermometer height

(*c*) Vessel — (*d*) Month — (*e*) Year — (*f*) Cruise

1	2	3	4	5		6		7	8	9		10	11	12		13		14	15	16	17	18
Time	Date	Latitude	Longitude	Wind		Air temp. °C		Barometer - mb	Weather	Clouds		Visibility	Surf. temp. °C	Sea		Swell		BT No.	Slide No.	Speed knots		Observer's initials
				Direction true	Speed	Dry bulb	Wet bulb			Formation	Amount			Direction	Amount	Direction	Amount					
				5.1	5.2	6.1	6.2			9.1	9.2			12.1	12.2	13.1	13.2					

TABLE 1. - BEAUFORT WIND SCALE AND ITS SPECIFICATION FOR SEA AND COASTAL USE

Beaufort scale number	Descriptive term	Coastal criterion [1]	Sea criterion
0	Calm	Calm	Sea like mirror.
1	Light air	Fishing smack just has steerage-way.	Ripples with the appearance of scale are formed but without foam crests.
2	Light breeze	Winds fills the sails of smacks which then travel at about 1-2 knots.	Small wavelets, still short but more pronounced. Crests have a glassy appearance and do not break.
3	Gentle breeze	Smacks under top sails, and make up to 3 knots.	Large wavelets, crests begin to break. Foam of glassy appearance. Perhaps scattered with white horses.
4	Moderate breeze	Good working breeze. Smacks under all sail heel over considerably.	Small waves becoming larger; fairly frequent white horses.
5	Fresh breeze	Smacks shorten sail.	Moderate waves, taking a more pronounced long form; many white horses are formed. Chances of some spray.
6	Strong breeze	Smacks have double reef in main sail. Care required when fishing.	Large waves begin to form; the white foam crests are more extensive everywhere. Probably more spray.
7	Near gale	Smacks remain in harbor and those at sea lie to.	Sea heaps up and white foam from breaking waves begins to be blown in streaks along the direction of the wind.

TABLE 1 - (*conclusion*)

Beaufort scale number	Descriptive term	Coastal criterion[1]	Sea criterion
8	Gale	All smacks make for harbor, if near.	Moderately big waves of greater length; edges of crests begin to break into spindrift. The foam is blown in well-marked streaks along the direction of the wind.
9	Strong gale		High waves. Dense streaks of foam along the direction of the wind. Sea begins to "roll." Spray may affect visibility.
10	Storm		Very big waves with long overhanging crests. The resulting foam, in great patches, is blown in dense white streaks along the direction of the wind. On the whole the surface of the sea assumes a white appearance. The rolling of the sea becomes heavy and shock-like. Visibility affected.
11	Violent storm		The conditions become progressively worse.
12	Hurricane		

[1] The fishing smack in this table may be taken as representing a trawler of average type and trim. For larger or smaller boats and for special circumstances, allowance must be made.

from a moving ship, it is advisable to draw a simple vector diagram to compute the true wind graphically from observations of the relative wind and the ship's speed and course (Figure 1). Wind speed, if measured by anemometers, should be recorded in knots or meters per second. Anemo-tachometers show the measured wind speed directly on the scale. With simple anemometers it is necessary to divide the measured windway by the number of observation seconds.

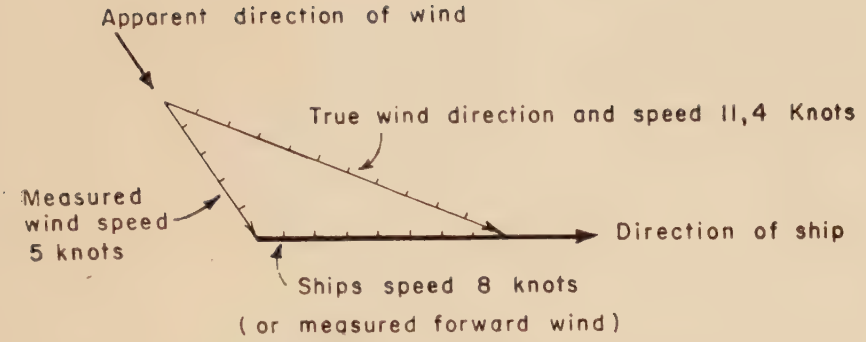

FIGURE 1. - Example of how to obtain true wind speed

2.2.1.3 BAROMETRIC PRESSURE

Pressure is measured either with a mercury barometer or with a precision aneroid. In the case of mercury barometers, the "pumping" effect should be allowed for when a reading is made. This characteristic and the amount of the pressure tendency are obtained with a barograph. Pressure and tendency should be recorded in millibars (for conversion see Table 3). For synoptic reports the pressure should be reduced to gravity at 45° latitude sea level and O°C, but for fisheries purposes such correction may be unnecessary.

Notes on Form 1. Meteorological data sheet (and BT data) [1]

The method of observation and codes to be used for filling this log are given in Section 2. Meteorological observations should be made at: (*a*) every station; (*b*) for every BT lowering; (*c*) the standard hour of observation while underway when the ship is reporting to meteorological offices.

(*a*) (*b*) State the anemometer and thermometer heights above sea level.

1. State Greenwich Mean Time

5.2. State the wind speed in knots if measured with anemometer, otherwise give the force in the Beaufort scale.

7. Give the uncorrected barometer reading in 2 digits neglecting 900 and 1000.

[1] In these notes the numbers refer to the column of the Form to which the note relates; letters refer to entries above the columns.

TABLE 5. - MARITIME CONVERSION SCALE FOR WIND SPEED

Beaufort number	Meters per second		Knots	
	mean	limits	mean	limits
0	0	< 0.6	0	1
1	1.5	0.7 - 2.3	3	1 - 4
2	3.4	2.4 - 4.4	7	5 - 8
3	5.6	4.5 - 6.6	11	9-12
4	7.8	6.7 - 8.9	15	13-16
5	10.2	9.0-11.3	19	17-21
6	12.6	11.4-13.8	24	22-26
7	15.1	13.9-16.4	29	27-31
8	17.7	16.5-19.0	34	32-36
9	20.4	19.1-21.8	39	37-42
10	23.3	21.9-24.8	45	43-48
11	26.5	24.9-28.2	52	49-55
12	—	28.2	—	55

2.2.2 **Air temperature**

To obtain a representative measure of air temperature, thermometers should be protected from the sun's radiation, both direct from the sky and reflected from surrounding objects, and at the same time they should be adequately ventilated. Mounted thermometers on ships are generally unsatisfactory. For routine observations there is no advantage in using thermometers which have very rapid response, since air temperature continually fluctuates a degree or two within a few seconds. Conventional thermometers should be read as rapidly as is consistent with accuracy in order to avoid changes of temperature due, for example, to breathing on the thermometer. At sea temperature is usually measured with a psychrometer (Figure 2) of which the dry

TABLE 3. - CONVERSION OF BAROMETRIC PRESSURE FROM MILLIMETERS TO MILLIBARS

mm	0 mb	1 mb	2 mb	3 mb	4 mb	5 mb	6 mb	7 mb	8 mb	9 mb	Decimals	
											Milli-meter	Milli-bar
680	906.6	907.9	909.2	910.6	911.9	913.2	914.6	915.9	917.2	918.6		
690	919.9	921.2	922.6	923.2	925.2	926.6	927.9	929.2	930.6	931.9	1	1
700	933.2	934.6	935.9	937.9	938.6	939.9	941.2	942.6	943.9	945.2	2	3
710	946.6	947.9	949.2	950.6	951.9	953.2	954.6	955.9	957.2	958.6	3	4
720	959.9	961.2	962.6	963.9	965.2	966.6	967.9	969.2	970.6	971.9		
730	973.2	974.6	975.9	977.2	978.6	979.9	981.2	982.6	983.9	985.2	4	5
740	986.6	987.9	989.2	990.6	991.9	993.2	994.6	995.9	997.2	998.6	5	7
750	999.9	1001.2	1002.6	1003.9	1005.2	1006.6	1007.9	1009.2	1010.9	1011.9	6	8
760	1013.2	1014.6	1015.9	1017.2	1018.6	1019.9	1021.2	1022.6	1023.9	1025.2	7	9
770	1026.6	1027.9	1029.2	1030.6	1031.9	1033.2	1034.6	1035.9	1037.2	1038.6	8	11
780	1039.9	1041.2	1042.6	1043.9	1045.2	1046.6	1047.9	1049.2	1050.6	1051.9	9	12
790	1053.2	1054.6	1055.9	1057.2	1058.6	1059.9	1061.2	1062.6	1063.9	1065.2		

Table 4. - Temperature conversion - Centigrade to Fahrenheit

°C	0.0	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9
−2	28.40	28.22	28.04	27.86	27.68	27.50	27.32	27.14	26.96	26.78
−1	30.20	30.02	29.84	29.66	29.48	29.30	29.12	28.94	28.76	28.58
−0	32.00	31.82	31.64	31.46	31.28	31.10	30.92	30.74	30.56	30.38
0	32.00	32.18	32.36	32.54	32.72	32.90	33.08	33.26	33.44	33.62
1	33.80	33.98	34.16	34.34	34.52	34.70	34.88	35.06	35.24	35.42
2	35.60	35.78	35.96	36.14	36.32	36.50	36.68	36.86	37.04	37.22
3	37.40	37.58	37.76	37.94	38.12	38.30	38.48	38.66	38.84	39.02
4	39.20	39.38	39.56	39.74	39.92	40.10	40.28	40.46	40.64	40.82
5	41.00	41.18	41.36	41.54	41.72	41.90	42.08	42.26	42.44	42.62
6	42.80	42.98	43.16	43.34	43.52	43.70	43.88	44.06	44.24	44.42
7	44.60	44.78	44.96	45.14	45.32	45.50	45.68	45.86	46.04	46.22
8	46.40	46.58	46.76	46.74	47.12	47.30	47.48	47.66	47.84	48.02
9	48.20	48.38	48.56	48.74	48.92	49.10	49.28	49.46	49.64	49.82
10	50.00	50.18	50.36	50.54	50.72	50.90	51.08	51.26	54.44	51.62
11	51.80	51.98	52.16	52.34	53.52	52.70	52.88	53.06	53.24	53.42
12	53.60	53.78	53.96	54.44	54.32	54.50	54.68	54.86	55.04	55.22
13	55.40	55.58	55.76	55.94	56.12	56.30	56.48	56.66	56.84	57.02
14	57.20	57.38	57.56	57.74	57.92	58.10	58.28	58.46	58.64	58.82
15	59.00	59.18	59.36	59.54	59.72	59.90	60.08	60.26	60.44	60.62
16	60.80	60.98	61.16	61.34	61.52	61.70	61.88	62.06	62.24	62.42
17	62.60	62.78	62.96	63.14	63.32	63.50	63.68	63.86	64.04	64.22
18	64.40	64.58	64.76	64.94	65.12	65.30	65.48	65.66	65.84	66.02
19	66.20	66.38	66.56	66.74	66.92	67.10	67.28	67.46	67.64	67.82

20	68.00	68.18	68.36	68.54	68.72	68.90	69.08	69.26	69.44	69.62
21	69.80	69.98	70.16	70.34	70.52	70.70	70.88	71.06	71.24	71.42
22	71.60	71.78	71.96	72.14	72.32	72.50	72.68	72.86	73.04	73.22
23	73.40	73.58	73.76	73.94	74.12	74.30	74.48	74.66	74.84	75.02
24	75.20	75.38	75.56	75.74	75.92	76.10	76.28	76.46	76.64	76.82
25	77.00	77.18	77.36	77.54	77.72	77.90	78.08	78.26	78.44	78.62
26	78.80	78.98	79.16	79.34	79.52	79.70	79.88	80.06	80.24	80.42
27	80.60	80.78	80.96	81.14	81.32	81.50	81.68	81.86	82.04	82.22
28	82.40	82.58	82.76	82.94	83.12	83.30	83.48	83.66	83.84	84.02
29	84.20	84.38	84.56	84.74	84.92	85.10	85.28	85.46	85.64	85.82
30	86.00	86.18	86.36	84.54	86.72	86.90	87.08	87.26	87.44	87.62
31	87.80	87.98	88.16	88.34	88.52	88.70	88.88	89.06	89.24	89.42
32	89.60	89.78	89.96	90.14	90.32	90.50	90.68	90.86	91.04	91.22
33	91.40	91.58	91.76	91.94	92.12	92.30	92.48	92.66	92.84	93.02
34	93.20	93.38	93.56	93.74	93.92	94.10	94.28	94.46	94.64	94.82
35	95.00	95.18	95.36	95.54	95.72	95.90	96.08	96.26	96.44	96.62
36	96.80	96.98	97.16	97.34	97.52	97.70	97.88	98.06	98.24	98.42
37	98.60	98.78	98.96	99.14	99.32	99.50	99.68	99.86	10.04	100.22
38	100.40	100.58	100.76	100.94	101.12	101.30	101.48	101.66	101.84	102.02
39	102.20	102.38	102.56	102.74	102.92	103.10	103.28	103.46	103.64	103.82
40	104.00	104.18	104.36	104.54	104.72	104.90	105.08	105.26	105.44	105.62
41	105.80	105.98	106.16	106.34	106.52	106.70	106.88	107.06	107.24	107.42
42	107.60	107.78	107.96	108.14	108.32	108.50	108.68	108.86	109.04	109.22
43	109.40	109.58	109.76	109.94	110.12	110.30	110.48	110.66	110.84	111.02
44	111.20	111.38	111.56	111.74	111.92	112.10	112.28	112.46	112.64	112.82
45	113.00	113.18	113.36	113.54	113.72	113.90	114.08	114.26	114.44	114.62
46	114.80	114.98	115.16	115.34	115.52	115.70	115.88	116.06	116.24	116.42
47	116.60	116.78	116.96	117.14	117.32	117.50	117.68	117.86	118.04	118.22
48	118.40	118.58	118.76	118.94	119.12	119.30	119.48	119.66	119.84	120.02
49	120.20	120.38	120.56	120.74	120.92	121.10	121.28	121.46	121.64	121.82

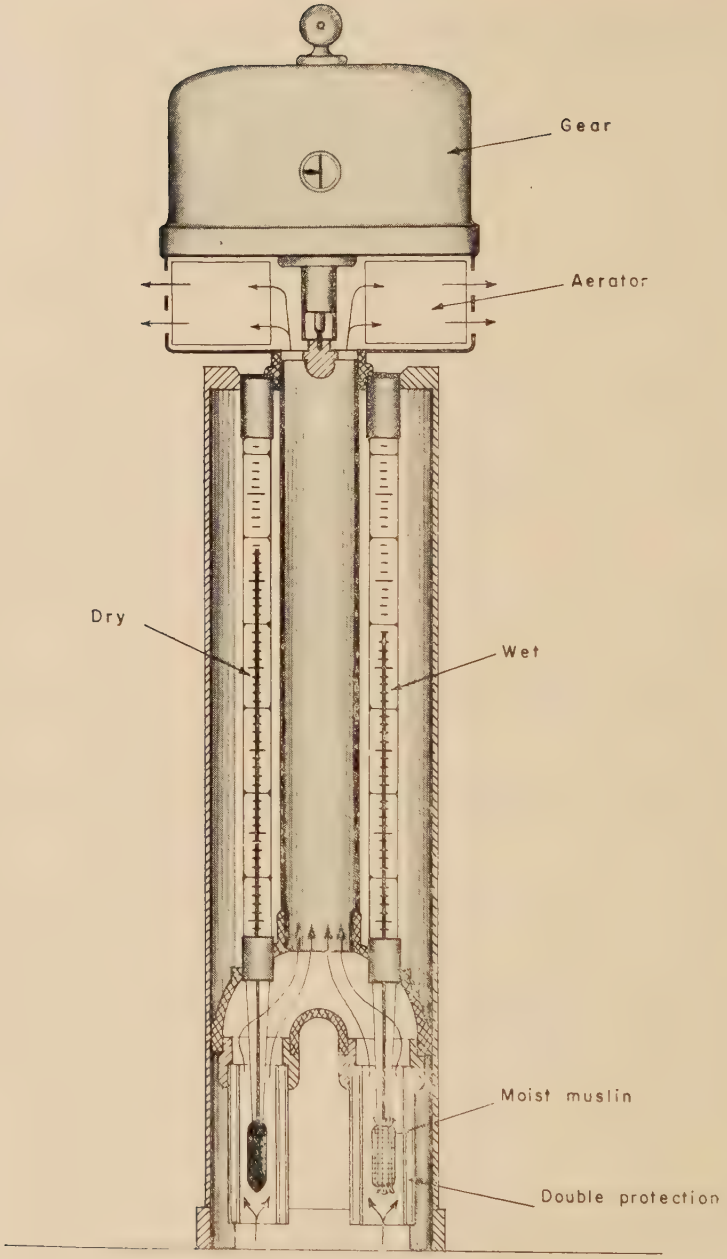

FIGURE 2. - Asmann's aspiration psychrometer

thermometer records the air temperature. (See further under Humidity measurements.)

There are several types of thermograph in use. The requirements for and the handling of these instruments is described in WMO Pub. No 8. It is usually sufficient to record the air temperature with an accuracy of ± 0.5°F or ± 0.25°C. (A Fahrenheit to Centigrade conversion table is given in Table 4.)

FIGURE 3. - Hair hygrometer
(Courtesy Fuess, Berlin - Steglitz)

2.2.3 **Humidity**

Air humidity is measured either with hygrometers (Figure 3) or psychrometers (Figure 2). The latter (the so-called wet and dry bulb thermometer) is the commonest form in use at sea. Psychrometers must be well exposed in a stream of air fresh from the sea. The wet bulb is moistened with distilled water. If the ventilation of the psychrometer is operated manually,

the thermometer must be read as soon as possible after ventilation has stopped. Psychrometers operated electrically (with battery) can be read during ventilation.

2.2.4 **Precipitation**

There are difficulties in the measurement of the amount of precipitation at sea and there are no satisfactory rain gauges for use on small vessels. Therefore, it is sufficient to record the kind and intensity of precipitation at the hour of observation and the weather of the previous hour by using the symbols in Table 5 and Figure 4.

2.2.5 **Clouds and weather**

The form, amount and direction of movement of clouds observed at sea should be recorded. The form can be noted by use of a cloud atlas. An abridged illustration of cloud forms is shown in Figure 5 and the code for cloud types in Table 6. The amount of cloud should be estimated in 1/8 of the sky, according to the code in Table 7. "Traces" of cloud should be included under scale No. 1 which should be used for amounts up to 1/8. "Overcast but with openings" should be included under scale No. 9. Direction of cloud movement should be reported at the direction from which the clouds come and should be expressed in 10° as for winds (01-36).

All weather phenomena, such as lightning and fog, should be recorded by the symbols in Table 8 or Figure 4.

The observer should be familiar with this Table before selecting code numbers to describe weather. It is sometimes advisable to select the corresponding decade number in the first vertical column and follow this line horizontally until the most correct description of the weather is found.

2.2.6 **Visibility**

To estimate visibility for higher ranges the appearance of the land when coasting is a useful guide if fixes can be obtained. In the absence of other objects, the appearance of the horizon, as observed from different levels in the ship, may be used as a basis of estimation by experienced observers. At night, navigation lights can give a useful indication of visibility. The visibility code is given in Table 9.

When visibility is not uniform in all directions, it should be estimated or measured in the direction of least visibility and the direction of observation suitably recorded in the log. It is useful also to indicate the cause of low visibility.

Table 5. - Beaufort weather notation

b.	Blue sky, weather with clear or hazy atmosphere
c.	Cloudy, i.e., either detached clouds or a cloud layer with openings
d.	Drizzle
e.	Wet air without rain falling, a copious deposit of water on trees, buildings or riggings
f.	Fog
fg.	Ground fog
fs.	Shallow fog
fe.	Wet fog
g.	Gale
h.	Hail
ks.	Drifting snow
kz.	Duststorm or sandstorm
l.	Distant lightning
m.	Mist: range of visibility 1,100 - 2,200 yards
o.	Overcast, i.e., the whole sky covered with a uniform layer of thick or heavy clouds
p.	Showers (use as prefix)
q.	Squalls
r.	Rain
vs.	Sleet, i.e., rain and snow together
s.	Snow
t.	Thunder
tl.	Thunderstorm
u.	Ugly, threatening sky
v.	Unusual visibility of distant objects
w.	Dew
x.	Hoar-frost
y.	Dry air (less than 60 percent relative humidity)
z.	Haze: range of visibility 1,100 - 2,200 yards
R.	Heavy rain
r.	(Moderate) rain
ro.	Slight rain
pr.	Rain showers
RR.	Continuous heavy rain
rr.	Continuous (moderate) rain
iro.	Intermittent slight rain
pS.	Heavy snow showers

FIGURE 4. - Forms of meteorological symbols
(*The meteorological glossary*. London, H.M.S.O.)

TABLE 6. - CODE FOR CLOUD TYPES

0.	Stratus or fracto-stratus
1.	Cirrus
2.	Cirro-stratus
3.	Cirro-cumulus
4.	Alto-stratus
5.	Alto-cumulus
6.	Strato-cumulus
7.	Nimbo-stratus
8.	Cumulus or fracto-cumulus
9.	Cumulo-nimbus

TABLE 7. - CODE FOR REPORTING CLOUDINESS

Scale number	*Amount of cloud*
0.	None.
1.	1 okta or 1/8 of sky covered
2.	2 oktas or 2/8 of sky covered
3.	3 oktas or 3/8 of sky covered
4.	4 oktas or 4/8 of sky covered
5.	5 oktas or 5/8 of sky covered
6.	6 oktas or 6/8 of sky covered
7.	7 oktas or 7/8 of sky covered
8.	8 oktas or sky completely covered
9.	Sky obscured (e.g., by fog) or amount of cloud not recordable owing to darkness

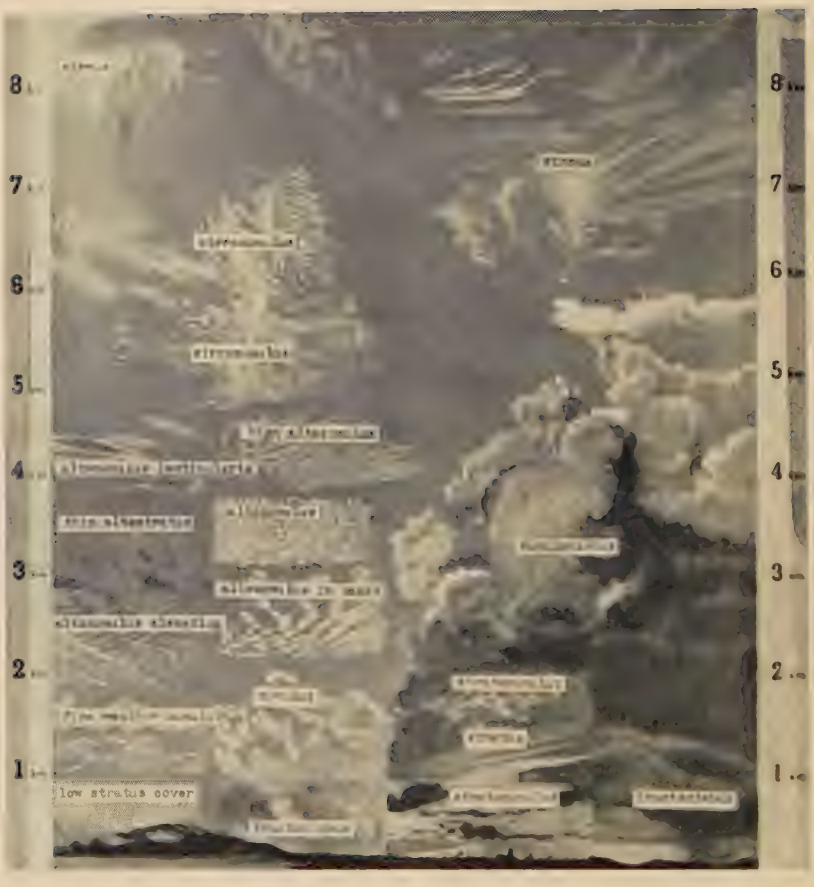

FIGURE 5. - Cloud forms

NUMERICAL WEATHER CODES—PRESENT WEATHER

00 Cloud development NOT observed or NOT observable during past hour	**01** Clouds generally dissolving or becoming less developed during past hour	**02** State of sky on the whole unchanged during past hour	**03** Clouds generally forming or developing during past hour	**04** Visibility reduced by smoke	**05** Haze	**06** Widespread dust in suspension in the air NOT raised by wind at time of observation	**07** Dust or sand raised by wind at time of observation	**08** Well developed dust devil(s) within past hour	**09** Duststorm or sandstorm within sight of or at station during past hour
10 Light fog	**11** Patches of shallow fog at station NOT deeper than 6 feet on land	**12** More or less continuous shallow fog at station NOT deeper than 6 feet on land	**13** Lightning visible no thunder heard	**14** Precipitation within sight but NOT reaching the ground	**15** Precipitation within sight reaching the ground but distant from station	**16** Precipitation within sight reaching the ground near to but NOT at station	**17** Thunder heard but no precipitation at the station	**18** Squall(s) within sight during past hour	**19** Funnel cloud(s) within sight during past hour
20 Drizzle (NOT freezing and NOT falling as showers) during past hour but NOT at time of ob	**21** Rain (NOT freezing and NOT falling as showers) during past hour but NOT at time of ob	**22** Snow (NOT falling as showers) during past hour but NOT at time of observation	**23** Rain and snow (NOT falling as showers) during past hour but NOT at time of observation	**24** Freezing drizzle or freezing rain (NOT falling as showers) during past hour but NOT at time of observation	**25** Showers of rain during past hour but NOT at time of observation	**26** Showers of snow or of rain and snow during past hour but NOT at time of observation	**27** Showers of hail or of hail and rain during past hour but NOT at time of observation	**28** Fog during past hour but NOT at time of observation	**29** Thunderstorm (with or without precipitation) during past hour but NOT at time of observation
30 Slight or moderate duststorm or sandstorm has decreased during past hour	**31** Slight or moderate duststorm or sandstorm no appreciable change during past hour	**32** Slight or moderate duststorm or sandstorm has increased during past hour	**33** Severe duststorm or sandstorm has decreased during past hour	**34** Severe duststorm or sandstorm no appreciable change during past hour	**35** Severe duststorm or sandstorm has increased during past hour	**36** Slight or moderate drifting snow generally low	**37** Heavy drifting snow generally low	**38** Slight or moderate drifting snow generally high	**39** Heavy drifting snow generally high
40 Fog at distance at time of observation but NOT at station during past hour	**41** Fog in patches	**42** Fog sky discernible has become thinner during past hour	**43** Fog sky NOT discernible has become thinner during past hour	**44** Fog sky discernible no appreciable change during past hour	**45** Fog sky NOT discernible no appreciable change during past hour	**46** Fog sky discernible has begun or become thicker during past hour	**47** Fog sky NOT discernible has begun or become thicker during past hour	**48** Fog depositing rime sky discernible	**49** Fog depositing rime sky not discernible
50 Intermittent drizzle (NOT freezing) slight at time of observation	**51** Continuous drizzle (NOT freezing) slight at time of observation	**52** Intermittent drizzle (NOT freezing) moderate at time of ob	**53** Continuous drizzle (NOT freezing) moderate at time of ob	**54** Intermittent drizzle (NOT freezing) thick at time of observation	**55** Continuous drizzle (NOT freezing) thick at time of observation	**56** Slight freezing drizzle	**57** Moderate or thick freezing drizzle	**58** Drizzle and rain, slight	**59** Drizzle and rain moderate or heavy
60 Intermittent rain (NOT freezing), slight at time of observation	**61** Continuous rain (NOT freezing) slight at time of observation	**62** Intermittent rain (NOT freezing) moderate at time of ob	**63** Continuous rain (NOT freezing) moderate at time of observation	**64** Intermittent rain (NOT freezing), heavy at time of observation	**65** Continuous rain (NOT freezing), heavy at time of observation	**66** Slight freezing rain	**67** Moderate or heavy freezing rain	**68** Rain or drizzle and snow slight	**69** Rain or drizzle and snow moderate or heavy
70 Intermittent fall of snowflakes slight at time of observation	**71** Continuous fall of snowflakes, slight at time of observation	**72** Intermittent fall of snowflakes moderate at time of observation	**73** Continuous fall of snowflakes moderate at time of observation	**74** Intermittent fall of snowflakes heavy at time of observation	**75** Continuous fall of snowflakes, heavy at time of observation	**76** Ice needles (with or without fog)	**77** Granular snow (with or without fog)	**78** Isolated starlike snow crystals (with or without fog)	**79** Ice pellets (sleet U. S. definition)
80 Slight rain shower(s)	**81** Moderate or heavy rain shower(s)	**82** Violent rain shower(s)	**83** Slight shower(s) of rain and snow mixed	**84** Moderate or heavy shower(s) of rain and snow mixed	**85** Slight snow shower(s)	**86** Moderate or heavy snow shower(s)	**87** Slight shower(s) of soft or small hail with or without rain or rain and snow mixed	**88** Moderate or heavy shower(s) of soft or small hail with or with out rain or rain and snow mixed	**89** Slight shower(s) of hail with or without rain or rain and snow mixed not associated with thunder
90 Moderate or heavy shower(s) of hail with or without rain or rain and snow mixed not associated with thunder	**91** Slight rain at time of ob thunderstorm during past hour but NOT at time of observation	**92** Moderate or heavy rain at time of ob thunderstorm during past hour, but NOT at time of observation	**93** Slight snow or rain and snow mixed or hail at time of observation thunderstorm during past hour but not at time of observations	**94** Mod or heavy snow or rain and snow mixed or hail at time of ob thunderstorm during past hour, but NOT at time of observation	**95** Slight or mod thunderstorm without hail but with rain and or snow at time of observation	**96** Slight or moderate thunderstorm with hail at time of observation	**97** Heavy thunderstorm without hail but with rain and or snow at time of observation	**98** Thunderstorm combined with duststorm or sandstorm at time of observation	**99** Heavy thunderstorm with hail at time of observation

A short meteorological code, useful for fishing (reporting and receiving of meteorological data by fishing vessels as well as for coding of data for logs) is given in Table 10.

TABLE 9. - VISIBILITY CODE

Code	Objects not visible at	Description
0	50 yards	Dense fog
1	200 yards	Thick fog
2	400 yards	Fog
3	1,000 yards	Moderate fog
4	1 nautical mile	Thin fog or mist
5	2 nautical miles	Visibility poor
6	5 nautical miles	Visibility moderate
7	10 nautical miles	Visibility good
8	30 nautical miles	Visibility very good
9	Over 30 nautical miles	Visibility excellent

Note: For eventual conversion into metric system 1 yard = 0.914 m and 1 nautical mile = 1.853 km.

2.2.7 Explanation of terms

ANEMOMETER. Instrument for measuring wind speed.

ANEMO-TACHOMETER. Instrument for measuring wind speed. The actual speed can be read directly on the scale.

ANEROID (BAROMETER). A barometer in which the action of atmospheric pressure in bending a metallic surface is made to move a pointer.

CLIMATOLOGY. The science which deals with climates and their effects.

GMT (UNIVERSAL TIME). Greenwich Mean Time. Time based on hour angle of point of definition of mean solar time as measured at Greenwich.

Table 10. - Meteorology code

For use of reporting ships in sparse areas

Group No 1 $YQL_aL_aL_a$

Y = Day of the week
1 = Sunday
2 = Monday
3 = Tuesday
4 = Wednesday
5 = Thursday
6 = Friday
7 = Saturday

Q = Longitude and hemisphere indicator

Northern hemisphere
0 = 0°– 90° West
1 = 90°–180° Wets
2 = 90°–180° East
3 = 0°– 90° East

Southern hemisphere
5 = 0°– 90° West
6 = 90°–180° West
7 = 90°–180° East
8 = 0°– 90° East

$L_aL_aL_a$ = Latitude in degrees and tenths.
Example: 31°28' South = 31.5
$L_aL_aL_a$ = 315

Group No. 3 Nddff

N = Cloud coverage
0 –
2 =
4 = (WMO-Specifications Code 60)
6
8 =
9 =

dd = True direction of the wind on the sea surface to the nearest 10°

dd = Pts of compass degrees

00	Calm	
02	NNE	20°
04	NE	40°
06		60°
08	ENE	80°
10	E	100°
12	ESE	120°
14	SE	140°
16	SSE	160°
18	S	180°
20	SSW	200°
22	SW	220°

Group No. 4 VVwwW

VV = Visibility
90 –
91 .
92 –
93 -
94 = (WMO-Specifications Code 84)
95 –
96 .
97 –
98 –
99 -

ww = Present weather
01 –
02 =
03 -
05 –
10 =
16 –
18 –
41 = (WMO-Specifications Code 92)
45 =
52 =
57 –
62 –

Group No. 5 PPXTT

PP = Last two figures of the barometric pressure in millibars.
Examples:
mb PP 30.32" = 1026.8 = 27
749 mm = 998.6 = 99

X = x (Indicator to show type of reporting ship)

TT = Outside air temperature in degrees F or C
Examples:

TT
57°F = 57
19°C = 19
6°C = 06
–2°C = 52

Note. 50 is added to temperatures below O °C

INSTRUCTIONS

1. In the interest of trans-ocean flying as well as safety of life at sea, your ship is earnestly requested to transmit radio weather reports when off the regular shipping routes.

Table 10. - Meteorology code

For use of reporting ships in sparse areas

Group No 1 $YQL_aL_aL_a$	Group No. 3 Nddff	Group No. 4 VVwwW	Group No. 5 PPXTT
Group No. 2 $L_0L_0L_0GG$	24 240°	67 =	2. The map provided shows clearly the areas from which weather reports are so urgently needed.
$L_0L_0L_0$ = Longitude in degrees and tenths. Example: 04°05' East = 04.1 $L_0L_0L_0$ = 041	26 WSW 260° 28 280° 30 WNW 300° 32 NW 320° 34 NNW 340° 36 N 360°	72 – 81 = 86 = 90 = 95 – Choose the largest figure applicable. 41-95: If no figure is suitable, put X in units position. E.g. 6x = rain when neither 62 nor 67 apply.	DISPLAY IT PROMINENTLY IN YOUR CHARTROOM
102°10' East = 102.2 $L_0L_0L_0$ = 022 (N.B. The "1" is omitted).	ff = Wind speed over sea surface in knots. Knots / Beaufort Force 00 Calm 02 1 05 2 09 3 13 4 18 5 24 6 30 7 37 8 44 9 52 10 60 11 68 12	W – Past weather (during the preceding 6 hours). 0 = 1 = 2 = 3 = 4 = (WMO-Specifications Code 90) 5 = 6 = 7 = 8 = 9 =	3. Address reports to: . . . . . . followed by the name of the nearest coastal radio station shown on the map. There is NO CHARGE to ships for Radio WEATHER messages to these stations.
GG = GMT of the observation to the nearest hour: 00 = 0000 GMT 06 = 0600 " 12 = 1200 " 18 = 1800 " N.B. Please take the observations as near to these times as possible.			4. The co-operation of all ships will enable Weather Services to provide better and more reliable shipping and aviation forecasts. 5. Whenever possible have your barometer checked and remember to apply the appropriate correction.

Humidity. The condition of the atmosphere in respect to water vapor.

Hygrometer. An instrument for determining the humidity of the air (see Figure 3).

Port Meteorological Officer. Officer appointed by the meteorological services of corresponding countries to assist and supervise the ships reporting meteorological data.

Psychrometer. An alternative name for the dry and wet bulb hygrometer (see Figure 2).

Rain gauge. An instrument for measuring the amount of rainfall.

Synoptic. A brief or condensed statement presenting a combined or general view of something; e.g., a synoptic chart shows the weather conditions over a large area at a given instant of time.

Wmo. World Meteorological Organization.

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Section 2. Observations on the physical and chemical environment

2.3 Oceanographic and limnological observations and analyses
2.3.1 Physical measurements

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2.3 OCEANOGRAPHIC AND LIMNOLOGICAL OBSERVATIONS AND ANALYSES

2.3.1 Physical measurements

Hydrographical observations are made and samples are taken at stations whose position is usually planned beforehand (see Section 1).

It is of the utmost importance that everything should be in readiness for the work of a station; all clearing up after each station should be done without delay, and log sheets should be prepared, instruments checked and cleared, and sampling bottles got ready, while the ship is underway from one station to another.

2.3.1.1 Hydrographic equipment

Practice is necessary for the proper handling and care of all instruments. It should always be borne in mind that since it is extremely difficult and often impossible to repair broken instruments on small vessels, the failure of an instrument may mean the failure of the entire program of work and a voyage may have been made in vain. Therefore, in addition to skill and care in handling, the instruments must be properly secured to the ship even during calm weather. An unexpected wave, when the sea is smooth, such as that generated by a passing ship, has often caused great damage in a ship's laboratory where no precautions had been taken. If possible, spare instruments should be carried.

Instruments should always be properly dried and cleaned immediately after use. Metal instruments should be rinsed with fresh water if possible. Greasing and degreasing is a regular job on certain types of oceanographical equipment. Silicon grease should be given preference.

Mounted hydrographic winches of different types are part of the ship's equipment and are not discussed here. Portable hand winches, used on small boats (Figure 1) must be securely fixed. These winches must have two brakes: one to regulate the lowering speed and a second to arrest the cable effectively. Cables, of which the best kinds are rustless, are strong and flexible; but nevertheless they must be handled carefully to avoid twisting, and should be checked often at wearing and weak spots. The weight at the end of the cable should be sufficient to allow different lowering speeds and to prevent sliding on the meter wheel. The meter wheel should be easily readable both by the winch and instrument operators (Figure 2).

Many different types of water samplers (bottles) are in use (Figures 3 to 5). These can be classified as single and series samplers. The most common single type is the Pettersson-Nansen bottle (Figure 3), which should not be used at greater depths than 200 meters. Series samplers either reverse themselves when closed by a "messenger," or are equipped with a reversible thermometer frame. A messenger is hung below each bottle. Reversing of the

FIGURE 1. - Hand winch
(Courtesy Bergen Nautik, Bergen, Norway)

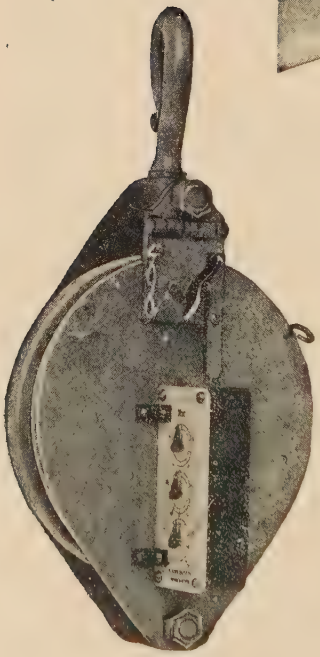


FIGURE 2. - Meter wheel
(Courtesy Bergen Nautik, Bergen, Norway)

bottles is initiated by sending down a messenger from the ship; this reverses the first bottle and releases its messenger which causes the second bottle to reverse, and so on. This chain reaction can be detected through the line so that if a bottle should not reverse and will not release its messenger, the observer will know that the action is incomplete. Bottles sometimes reverse and close prematurely (*a*) if the end weight is too light, (*b*) if the cast is lowered too rapidly and (*c*) in heavy seas. Care should be taken that the bottles are fastened to the wire, so that no sliding occurs and that they remain open until the messenger strikes them.

2.3.1.2 Current measurements

Whenever possible, surface currents should be observed and recorded in the scientific logs. Allowances must be made in coastal waters for tidal currents which are superimposed on permanent or temporary currents caused by other phenomena such as wind. There are several methods, direct and indirect, for measuring and estimating currents.

2.3.1.2.1 *Direct measurements*

The direction and relative velocity of currents can be determined visually by observing the sea surface around anchored buoys, single small rocks, or similar objects. The accumulation of floating detritus on the surface sometimes gives an indication of the convergence lines of currents. The cheapest and simplest equipment for surface current observation from anchored vessels is a current cross (Figure 6). The line to which a cross is attached must be light in weight and marked in meters or fathoms. The length of line pulled out by the current cross per unit of time gives the speed: direction is estimated from the direction of the line. When measuring subsurface currents with current crosses the area of the cross must be much larger than the surface of the buoy from which the cross is suspended. At night the buoy can be equipped with light. If the vessel is equipped with radar, a radar reflector on the buoy will facilitate the operation. There are several types of direct-reading current meters for use on anchored ships. If only one anchor is being used, the swinging of the ship around the anchor must be taken into account and the measurements taken several times. In areas with tidal currents the measurements should be made at intervals during at least two tidal periods.

The Carruthers simple current meter uses a bottle, half filled with jelly and a compass floating in it. This meter is especially useful for measuring bottom currents. The bottles are sent down fixed to a weight or to a special neutrally buoyant holder in the desired depth by means of anchored buoys. The jelly bottle is tilted by the current, the cold water solidifies the jelly and the amount

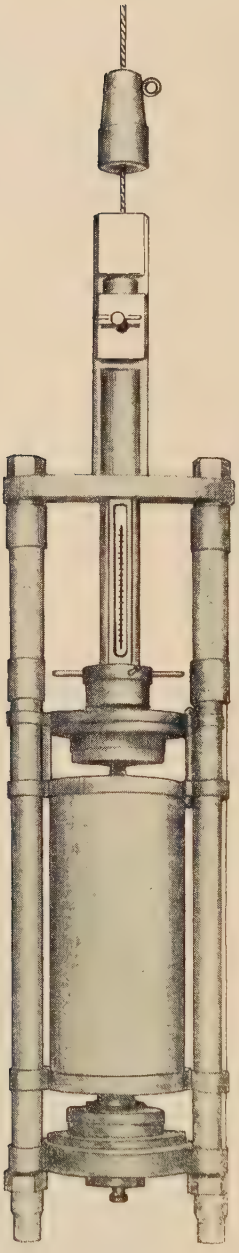


FIGURE 3. - Pettersson-Nansen bottle

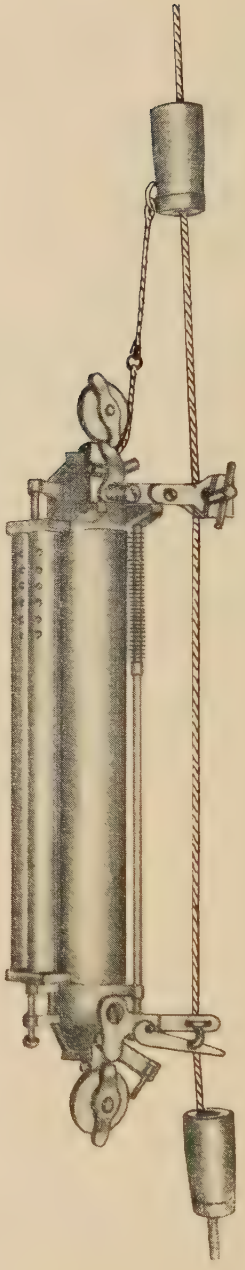
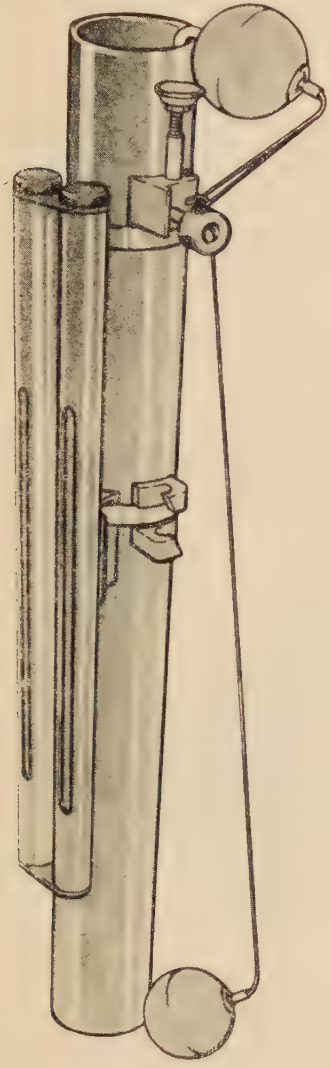


FIGURE 4. - Nansen reversing water bottle

of tilt gives, from calibration tables, the current speed. The compass gives the direction of tilt, hence the direction of current (Figure 7).



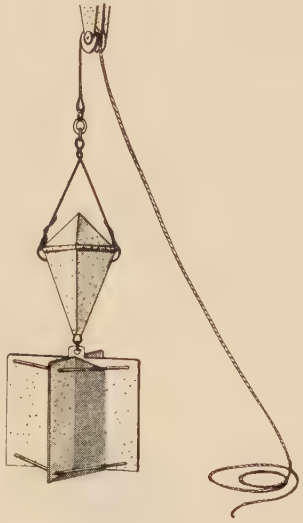


FIGURE 6. - Current cross

FIGURE 5. - Frautschy bottle
(Courtesy Hytech Corp., Inglewood, Calif., U.S.A.)

The Ekman current meter (Figure 8), the most common in use in the past, needs careful handling. The operator must check that the propeller turns in friction-free manner and that the release and closing mechanisms work properly. Sufficient weight below the meter should be used to keep the meter horizontal

in the water, otherwise the special compass in the meter will not function properly. Movement of the ship in waves causes considerable errors in the Ekman and other propeller-type current meters suspended from the ship.

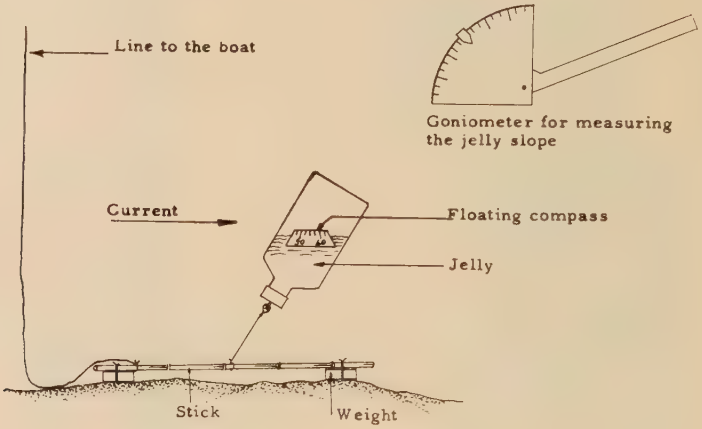


FIGURE 7. - Carruther's jelly bottle

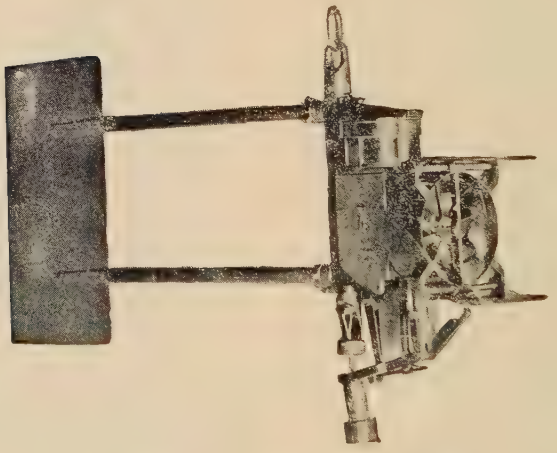


FIGURE 8. - Ekman current meter
(Courtesy Bergen Nautic, Bergen, Norway)

Continuous current meters are available, which record currents and their direction for two weeks. These are suspended in the water by buoys and anchors. There are also several other types of simple current meters, such as Carruthers current cones, etc. A more expensive and complicated instrument for measuring surface currents is the Geomagnetic Electro Kinematograph

(G.E.K.). This works on the principle that an electric current is induced when a body of water moves in the earth's magnetic field. Special skill is needed for handling this instrument.

2.3.1.2.2 *Indirect methods*

In offshore waters currents may be computed from the drift of the ship. This drift is determined by the difference in unit time of the fix of the ship estimated from its course and speed and the astronomical fix. Drift cards and drift bottles are often used. The bottles are filled with sand so that when floating only a small part of the neck projects through the surface. A card is enclosed in the bottle with a number and the address to which the finder should send the card, and a request to the finder to record the date and location of discovery of the bottle. The place and date of release and number are recorded and compared with place and date of recovery. Drift bottles are generally used in semiclosed basins to investigate special features of the surface currents. They give only a rough picture of current paths. The bottles are influenced by winds and waves, and these and other factors must be considered when evaluating the results.

Conclusions about the current patterns can also be drawn from ecological indicators (mainly plankton and suspended matter).

2.3.1.2.3 *Determination of stream flow*

Average width and depth. A series of measurements is made of the stream station. At least five measurements should be taken of the width of each station; each end, middle, and midway between these are usually taken. More measurements should be made if the stream is particularly uneven. The average is then obtained.

Depth is measured at points of width measurement. Depth is taken in the middle of the stream, and at a point halfway between the middle and each shore. If the stream is wide or the bottom uneven, more than the three soundings should be taken. The average depth is determined by adding the readings and dividing by one more than the number of soundings taken. This allows for the zero readings at the shore.

Volume. Volume will be recorded in cubic meters per second where the flow is greater than 1 m^3. Flows less than 1 m^3 should be given in liters per minute (1 min^{-1}).

The following formula is used to determine the volume flow:

$$R = \frac{W\ Da\ L}{T}$$

Where R is rate of flow

W is average width of section

D is average depth of section

T is average time in seconds required for a float to traverse the distance L

L is the length of the stream section

a is a constant for correction of stream velocity. If the bottom is rough and strewn with rocks and coarse gravel, a is taken as 0.8; if the bottom is smooth a is taken as 0.9.

As straight a section of stream as possible is selected for this test. Measure the length, width and average depth of this section. Then ascertain the length of time it takes for a small float (about the diameter of a lead pencil and 75 mm long) to traverse the distance. Three trials should be run with the float, and the average time recorded.

Substitute the proper figures in the formula and determine the volume flow.

Velocity. Velocity may be described in terms of centimeters per second flow according to the following table:

Very slow	0-10	cm per second
Slow	11-25	" " "
Moderate	26-50	" " "
Moderately rapid	51-75	" " "
Rapid	76-100	" " "
Very rapid	101-200	" " "
Torrential	201 and above	

2.3.1.3 Temperature measurements and corrections applied

2.3.1.3.1 *Surface temperature*

It is advisable to record sea surface temperature at frequent intervals when the ship is underway because rapid changes in temperature with distance are generally indicative of current divergences and convergences whose presence is always of considerable significance. The temperature of surface seawater (the upper 50 cm) can easily be measured by the "bucket" method while underway. In large ships the temperature of condenser intake water is recorded continuously.

For temperature determination the sample of water should be taken with a special bucket on the leeward side far from all outlets. The bucket should not have been in direct sunshine prior to use. It should be towed astern for at least three minutes. If the bucket is equipped with a special fixed thermometer, this should be read immediately the sample arrives on board. When a loose thermometer is used, it is held by the upper end and moved around in the water for a minute or two. The thermometer should have a small heat

Form 1. - Stream survey

Name of stream ..... Main drainage .....

Stream section .....

Watershed: Cultivated or not, wooded, open swampy, flat, rolling, hilly, mountainous .....

Bank vegetation: .....

Aquatic vegetation - Algae: Abundant ..... Common ..... Rare .....

Higher plants: Abundant ..... Common ..... Rare .....

Irrigation pumps, diversions, barriers, dams .....

Pollution .....

Water supply: Present level ..... High-water level .....

Gradient: Slight ..... Moderate ..... Steep .....

Pools: Size ..... Type ..... Frequency .....

Spawning areas: None Few Common ..... Abundant .....

Stream bed: % Bedrock ..... % Rubble ..... % Gravel ..... % Sand .....

% Mud ..... % Silt ..... % Boulders .....

Fish present .....

Average width ..... Average depth .....

Volume flow ..... Velocity .....

Color ..... Turbidity ..... Water temp. ..... Air temp. .....

pH ..... O_2 ..... CO_2 ..... MO Alkalinity ..... ph-th .....

Investigator .....

capacity and it should not be lifted out of the water for reading. The reading should be made with an accuracy of + 0.2°F or + 0.1°C. A surface bucket is illustrated in Figure 9.

2.3.1.3.2 *Temperature in the depths*

Water samplers are usually fitted with frames to hold two reversible thermometers (Figure 10). One thermometer is protected against pressure and the other is unprotected. The unprotected thermometer serves for checking and/or recording the depth to which the sampler has been lowered. Simpler and cheaper samplers, which are often suitable for fisheries work (e.g. the Frautschy bottle), have usually one reversible thermometer (pressure protected).

The cast is made from a work platform or from the weather side of the ship, and the depth of the water must be checked from the bridge before the cast. If possible, samples should be taken at standard depths of observation: 0, 10, 20, 30, 50, 75, 100, 150, 200, (250), 300, 400, 500, 600, (700), 800, 1,000, 1,200, 1,500, 2,000, 3,000, 4,000 meters. At least five minutes should pass after a cast has been lowered into position before the messenger is sent to close the bottles, to allow each thermometer to register the temperature of the water layer in which it lies. Before the messenger is dropped the angle of the wire with the sea surface is measured, so that the actual depth of the samples can be calculated. In rough weather when hauling in, care must be taken that the bottles do not hit against the ship. When the samplers are hauled aboard and loosened from the wire, care must be taken not to turn them on their sides but place them vertically into the rack as they come from the water.

The thermometers should be read with a thermometer reader, the main one to an accuracy of $\pm$ 0.01°C and the auxiliary to $\pm$ 0.1°C. The auxiliary thermometer shows the temperature of the thermometer at the time of reading and serves for correction of the actual temperature.

Bathythermographs (Figure 11) are used for continuous recording of temperature and depth in upper water layers. The BT can be lowered either at the station or underway. The record is made by the instrument on smoked slides, one of which is used for each lowering. In operation the BT is lowered into the surface water and held there for about 30 seconds to allow the thermometer to adjust to the temperature of the sea surface.

After that more wire is paid out. The length of wire run out during underway measurements depends on the ship's speed and the condition of the control gear. Several trial runs should be made to determine the length of wire necessary to reach the depths sought. The surface temperature should always be taken with the bucket thermometer when the BT is lowered and recorded in the BT log. The BT should never be kept in temperatures exceeding 105°F (40°C).

The slides are numbered and kept in special boxes. A special magnifying glass with graded scales for depth and temperature is used to read these slides.

Exact instructions for the use of the BT are given in Section 2.3.1.3.4.

FIGURE 9. - Surface bucket with thermometer

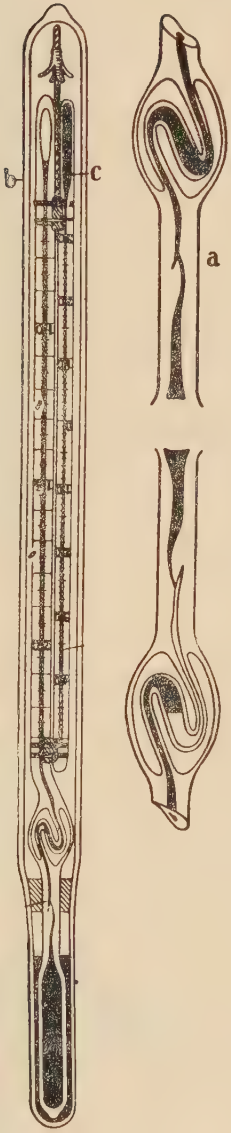


FIGURE 10. - Reversing thermometer (pressure protected)

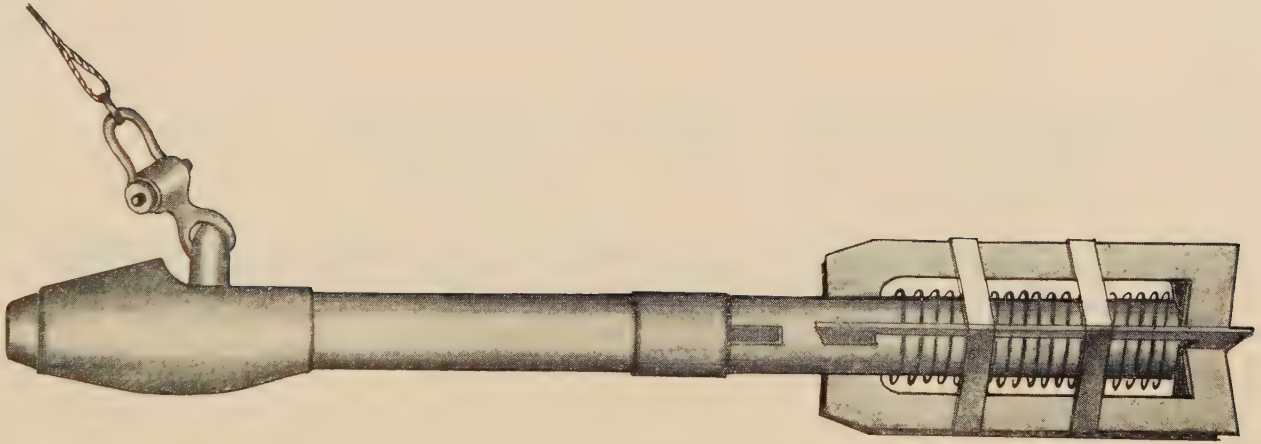
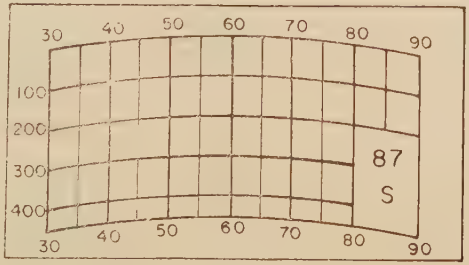
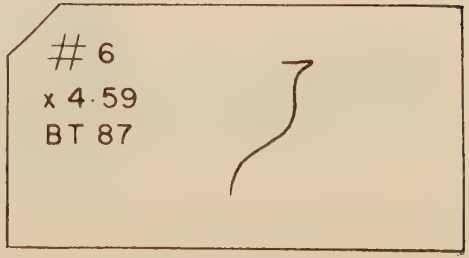


FIGURE 11. - Bathythermograph



Grid for reading recording



Typical recording

BTs provided with water samplers are also available (so called "sea samplers"). Those samplers take samples automatically at selected depths during the lowering of the BT. However at present none of the sea samplers available are entirely satisfactory: all the water bottles tend to leak, and the samples are relatively small and permit only determination of salinity.

2.3.1.3.3 *Reading, correction and care of reversing thermometers*

(The following is an extract from an undated mimeographed paper *Measurement of sea temperature and corrections applied*, by T.G. Thompson, R.J. Robinson and C.A. Barnes. Seattle, University of Washington.)

Each reversing thermometer consists of two thermometers, the reversing thermometer proper and the auxiliary thermometer. These are sealed in a heavy glass tube in order to prevent the pressures at the greater depths from having an effect upon the mercury bulbs proper. The larger bulb of the reversing thermometer is immersed in a mercury jacket contained in the heavy glass tube. This arrangement permits rapid conduction. The capillary tube of this thermometer is contracted just above the large bulb so that when the instrument is inverted the column of mercury breaks at the contraction. Part of the mercury falls into the small bulb and overflows, filling part of the graduated stem. The actual volume of mercury flowing into the small bulb is dependent upon the temperature of the mercury at the time of reversal of the instrument.

The scale on the thermometer has the lowest values at the small bulb, but the stem is graduated with respect to the mercury contained originally in the large bulb. A correct reading of the thermometer is possible only when it is read at exactly the same temperature as that at the time of reversal and when the graduations are exact. If the temperature at the time of reading is greater than at the time of reversal, the mercury in the small bulb will have expanded. To obtain the actual temperature, a correction for this must be made and the purpose of the auxiliary thermometer is to give a means for making this correction. A change in the volume of the mercury corresponds to a change in temperature as recorded on the scale of this thermometer, while in the reversing thermometer a change affects only that portion of the mercury contained in the smaller bulb after the thermometer has been reversed.

The two thermometers will have the same reading at the time when the mercury column of the reversing thermometer is broken by reversal, and any differences between their readings at any other temperature will be proportional to the difference between this temperature and that at the time of reversal. This ratio is a function of the volume of mercury in the smaller bulb and the capillary of the reversing thermometer. If the thermometers are read simultaneously, a means is provided whereby the temperature at the time of reversal, or in other words the actual temperature of the water, may be computed.

CORRECTION OF REVERSING THERMOMETERS

Two corrections must be applied to the readings of reversing thermometers, namely, the index correction and the temperature-difference correction (the difference between the reading of the reversing thermometer and the auxiliary thermometer).

The index correction, I, is determined by the actual calibration of the thermometer at different temperatures and is dependent solely on the thermometer reading. The correction arises from the slight irregularities in the capillary tube of the thermometer. Many of the reversing thermometers in use have been calibrated by the United States Bureau of Standards, the Physikalisch-Technische Reichsanstalt (P.T.R.), or the National Physical Laboratory (United Kingdom). Upon calibration, these laboratories furnish certificates giving the corrections necessary for several readings of the thermometer. This correction, or index correction, must be added or subtracted. Upon testing reversing thermometers, these laboratories may subject them to a pressure test and the certificate of calibration may bear a phrase: "The action of this instrument was found to be satisfactory after being submitted to a pressure of three tons per square inch." Such a statement indicates that the thermometer may be used down to depths approximately of 4,500 meters without fear of crushing the thermometer by hydrostatic pressure.

The temperature-difference correction is a correction made for the expansion of mercury in the main thermometer and is a function of the amount of mercury in the smaller bulb and the capillary tube; the difference in the temperatures of the main thermometer and the auxiliary thermometer and the nature of the glass comprising the thermometer. If a thermometer is reversed in a layer of cold water and then brought to the surface through a layer of warm water, the mercury in the bulb and capillary of the main thermometer will expand and thus the reading of the main thermometer must be corrected for this expansion. In order to do this, the volume of the thermometer bulb up to the reading of 0° on the capillary must be known and such volume, designated as the degree volume, is given on each thermometer. The total temperature correction, $\triangle T$, may be calculated from the following formula:

$$\triangle T = E + I$$

where $\triangle T$ is the total correction, E the temperature-difference correction, and I the index correction.

$$E = \left[\frac{(T' + V_o)\ (T' - t)}{K}\right]\left[1 + \frac{(T' + V_o)\ (T' - t)}{K}\right]$$

T' = Reading of the main thermometer after reversal.

t = Reading of the auxiliary thermometer after reversal.

V_o = The degree volume of the thermometer, or the volume of mercury in the thermometer at 0°C.

K = A constant expressing the relative thermal coefficient of mercury and the glass of which the thermometer is made.

The constant K is a function of the quality of the glass comprising the thermometer. Most of the reversing thermometers in use are from Jena glass 59^{iii} or Jena 16^{iii}. For Jena 59^{iii}, $K = 6{,}100$, and for Jena 16^{iii}, $K = 6{,}300$.

Substitution of $K = 6{,}100$ in the above equation reduces it to

$$E = [0.000164\ (T' - t)\ (T + V_o)]\ [1 + 0.000164\ (T' + V_o) + 0.000164\ (T' - t)]$$

The temperature-difference correction, E, may be ascertained directly from the tables by knowing the values for T', t, and V_o. The true temperature T^o may be found from the equation

$$T^o = T' + \triangle T$$

Illustration: The main thermometer reads 11.00°C, the auxiliary thermometer, 21.0°C, and the degree volume of the main thermometer is 89°C.

$$(T' - t) = -10 \qquad (T' + V) = 100$$

Reference to the table shows that E is -0.167°C. and for most practical purposes becomes -0.17°C. The index correction, found by the calibration of this thermometer is $+.02$°C. The total correction is

$$\triangle t = -.17^o + .02^o = -.15^o$$

and the true temperature

$$T^o = 11.00 - .15 = 10.85^o$$

If a great number of temperatures have to be corrected, it is advisable to construct graphs for this purpose. A detailed description for the construction and use of such graphs is given by Emilsson (1954).

Notes on Form 2. - Thermometer arrangement sheet

A thermometer arrangement sheet is prepared in duplicate before every cruise or when the arrangement is changed during the cruise.

When a thermometer fails to function properly and is replaced, a new arrangement sheet must be completed.

(*c*)/(*d*) State the date when the sheet is prepared and the name of the arranger.

(*b*)/(*e*) Give the numbers of stations and the dates where and when this arrangement is used.

FORM 2. - THERMOMETER ARRANGEMENT SHEET

(*a*) Cruise No.	(*b*) Stations No.			to No.				(*c*) Date prepared / (*e*) Date used	(*d*) Prepared by / to
1 Nansen bottle No.	2 Left thermometer			3 Right thermometer				(*f*) Arrangement changed by	(*g*) Date and hour
	2.1 P. No.	2.2 V_o	2.3 I	3.1 U. No.	3.2 V_o	3.3 I	3.4 1/Q m Factor	(*h*) checked by	(*i*) Vessel dates
								j Remarks	

(*f*)/(*g*) Indicate the date and hour when this arrangement is changed and a new sheet is prepared.

2.1 P. No. - Number of protected thermometer.

3.1 U. No. - Number of unprotected thermometer.

2.2/3.2. V_o - The mercury volume at 0°C. (Obtained from the thermometer calibration sheet.)

2.3/3.3 I - Index correction of the main thermometer scale. (Obtained from the thermometer calibration sheet.)

3.4 1/Q m - The "pressure factor" for unprotected thermometers.

THE FUNCTION AND CARE OF REVERSING THERMOMETERS

By observing the breaking point of the mercury column in the main thermometer, namely at the top in the coiled end of the capillary where it joins the small dead arm, it is possible to ascertain whether or not the thermometer is in proper condition.

When the thermometer is held in a vertical position with the large bulb at the bottom, there should be no air in any part of the capillary. Upon reversing the thermometer, so that the large bulb is at the top, the mercury should break at the point shown by the lower arrow in (b) (Figure 12). Observation is facilitated by the use of a magnifying glass. Upon repeating this operation very slowly, the mercury must first run out of the side arm as shown in (a). During this process, care should be taken not to touch the bulb with the hand, for a temperature change makes an exact observation of the breaking point impossible. The separated column of mercury, which breaks at the side arm, runs downward into the smaller bulb and graduated capillary of the main thermometer and thus corresponds to the temperature prevailing at the time of reversal. If, after the breaking of the mercury thread, the thermometer is reversed to its original position, the mercury must run out of the smaller bulb and capillary and join the mercury in the main bulb at the dead arm. Under such conditions it may be assumed that the thermometer is functioning properly.

IMPROPER FUNCTIONING OF THE REVERSING THERMOMETER

As a result of improper handling, such as in transportation, sudden blows, or remaining in a horizontal position for a protracted period of time, the mercury may no longer form a connected thread and behave as described above. The difficulty then observed may fall into one of the three categories as follows (Figure 12).

(a) *Mercury remains in the upper portion of the smaller bulb*

After reversing the position of the thermometer so that the large bulb is below, some of the mercury may remain in the smaller bulb. This condition is illus-

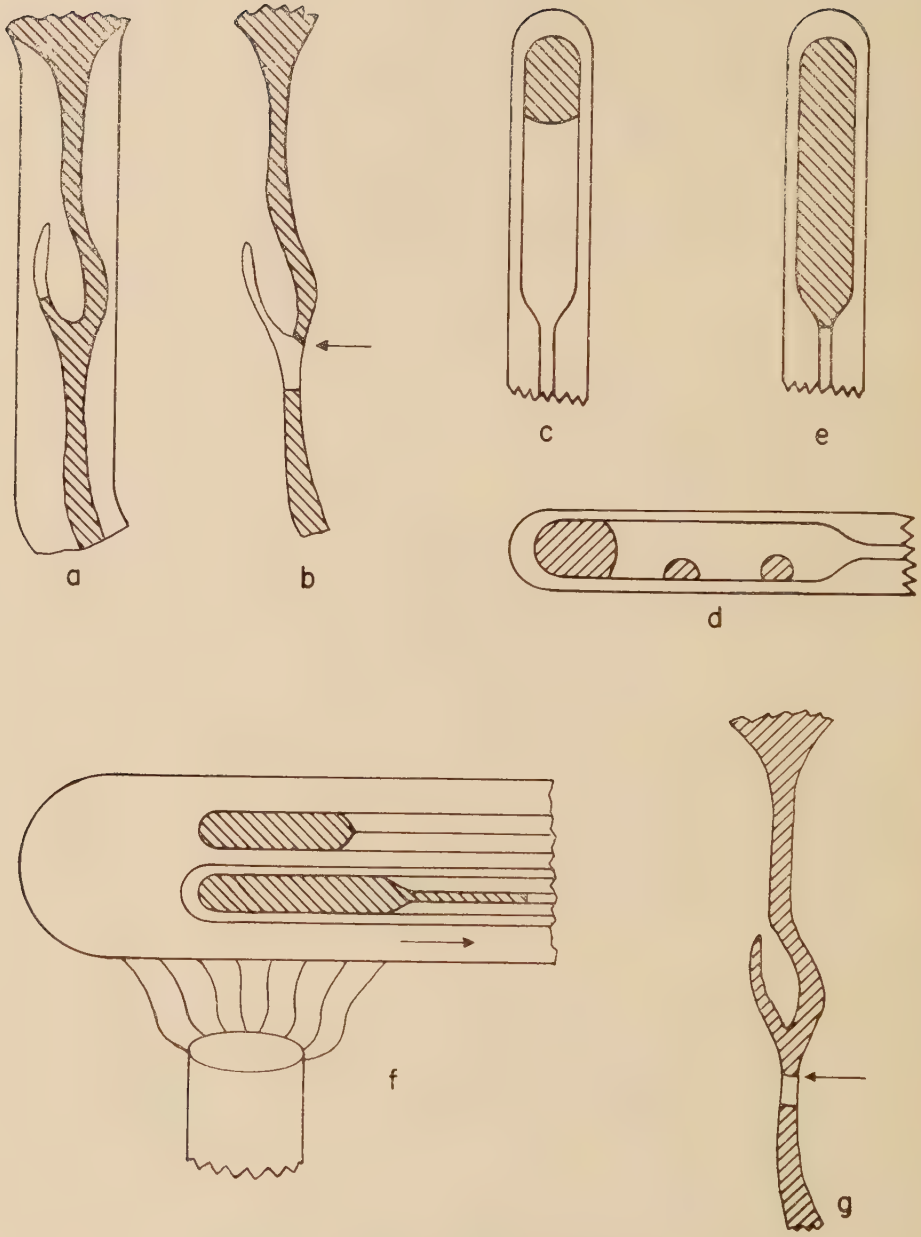


FIGURE 12. - Care of reversing thermometers

trated in (c). In many cases, it is sufficient to reverse the thermometer again. When the mercury flowing from the large bulb is united with that which remained in the smaller bulb and the thermometer is again turned to its original position, proper functioning of the mercury is observed.

If this does not occur and part of the mercury still stays in the smaller bulb, a small particle of air, generally observable with a magnifying glass, is the cause of the difficulty. To remedy this situation, hold the thermometer by the large bulb in a horizontal position in the right hand and then gently tap the other end of the thermometer in the palm of the left hand until several globules of mercury separate in the small bulb as shown in (d). The thermometer is then carefully inverted so that the mercury runs into the smaller bulb. As soon as it touches the small globules that have been separated, turn the thermometer again to its original position. The separated globules are thus drawn into the main bulb. Several more globules are again separated and the process repeated until all the mercury is reunited.

Under no circumstances hold the thermometer in a vertical position with large bulb downward and jar by tapping. If this is done, the air bubble may eventually be forced into the dead arm of the lower capillary and the thermometer will be ruined.

(b) *Mercury remains in smaller bulb, breaking at capillary*

This undesirable situation is shown in (e). To remedy it, hold the thermometer in a horizontal position and warm the smaller bulb over a small bunsen flame, as illustrated in (f), constantly rotating the thermometer. The mercury in the auxiliary thermometer rises at the same time and care must be exercised in order that no breaking of the mercury thread occurs. During the heating, the thermometer should occasionally be brought to a vertical position to see if heating has been sufficient so that the mercury runs down the capillary to the large bulb. If this occurs, the small air bubble is pushed downward into the main bulb. Examination may show that the mercury thread breaks at the proper place and that the thermometer functions normally. However, before it is used, the zero point should be checked by immersing the instrument in ice.

If the air bubble is in the looped capillary or the mercury thread does not break at the proper place, the procedure recommended below should be followed.

(c) *The mercury thread does not break at proper place*

Such a situation is illustrated in (g). To correct this defect the thermometer is placed in a vertical position, large bulb downward, and when a continuous mercury thread has formed cool the bulb to a very low temperature, immersing, if necessary, in a salt-ice mixture. Holding the thermometer at the looped capillary, quickly reverse it with a jerk. The thread will break at the air bub-

ble and may also break at the usual place. After the smaller bulb is filled with the mercury, turn the thermometer to a horizontal position and warm the larger bulb slowly and carefully to about 60°C. The air bubble is driven forward. Return thermometer to original position and cool. This process of alternate cooling and heating is continued until the air bubble is above the mercury. When the thermometer begins to function normally again, it is best to check the zero reading by inserting in melting ice.

2.3.1.3.4 *Measurement of temperature with the bathythermograph*

(By John P. Tully. Extracted from: *Manual of oceanographic methods.* (1950) Nanaimo, B.C., Canadian Joint Committee on Oceanography, Pacific Oceanographic Group. Mimeo.)

MECHANISM

Temperature device

Forty-five ft (13.7 m) of copper capillary tube operating a Bourdon tube.

Pressure (depth) device

Sylphon bellows with slide carriers, spring tension 320 lbs (145 kg), compresses spring 1 in.; 450 ft (137 m) depth = 225 lbs (102 kg), compresses spring 0.7 in. (18 mm).

Recording device

A smoked glass slide is carried in an adapter fitted rigidly to the sylphon bellows, and moves with pressure on the long axis of the BT. A stylus fitted to the Bourdon tube moves with temperature on transverse axis.

The resultant motion is recorded by the scratch left by the stylus on the smoked glass slide.

Accuracy

A difference of 0.1°F (0.05°C) can be recognized in the temperature-depth curve, if the instrument and slides are good. Normally 0.2°F (0.1°C) precision is expected and obtained. The absolute accuracy depends on the accuracy of the index observation.

Slides

These are smoked glass (1 in. × 1 3/4 in.) (25 mm × 44 mm) made by moistening the glass with oil and smoking in the yellow flame of an oil lamp.

Calibration grid

Each instrument is placed in a pressure tank and a series of calibrations is made at known temperatures and pressures. This is amplified to show depths at 10 ft (3 m) intervals, and temperature at 1°F (0.5°C) intervals. The instrument should be recalibrated every time an adjustment is made. Naval Research Establishment, H.M.C. Dockyard, Halifax, Woods Hole Oceanographic Institution at Woods Hole, Massachusetts, and Scripps Institution of Oceanography at La Jolla, California, are equipped to calibrate instruments.

RIGGING

The BT is secured to a sounding line (1/32 in. or 1/16 in.) (0.8 mm or 1.6 mm) galvanized steel sounding line, or equivalent. The line is led from a sounding machine (Kelvin), or suitable winch, over a travelling block on a boom leading well clear of the ship's sides.

PROCEDURE

Preserving the slide

First make index notations on the slide and dip it in fresh water, and finally in amyl-acetate lacquer, and dry.

Preserving records

The temperature record may be examined at once by placing it over the standard grid in the viewer provided. It is customary to make the date permanent by a photographic enlargement of the slide, and its calibration grid, on the back of which all pertinent data are recorded.

2.3.1.4 Calculation of actual depth

A rough estimate of the depths at which the water bottles of a cast are reversed in the sea may be obtained from the wire angle (the angle the wire makes with the vertical) at the sea surface, and the length of wire to each bottle. However, this method assumes that the curvature of the wire below the surface is known, an assumption which is not valid to great depths. The method is satisfactory only for depths of less than 100 meters with large wire angles, and to several hundred meters with angles less than 5°.

The customary method of determining depth of sampling when the wire angle is greater than 5° is by comparing the corrected readings of the protected and unprotected deep-sea reversing thermometers.

The correction of the unprotected thermometer which is used in conjunction with the protected thermometer is a simpler calculation because the temperature of reversal of the latter is known. The correction is determined from:

$$\triangle T = \frac{(Tw - t)\ (T' + V_o)}{K} + I$$

Tw = Temperature of reversal of the protected thermometer.
t = Temperature of the auxiliary thermometer of the unprotected thermometer.
T' = Reading of the unprotected thermometer.
V_o = Degree volume of the unprotected thermometer.
K = 6100
I = Index correction.

From the corrected readings of the protected and unprotected thermometers, the depth at their reversal may be computed from the equation:

$$D = \frac{(Tu - T)}{Qd}$$

Where D = Depth in meters.
Tu = Corrected reading of unprotected thermometer.
T = Corrected reading of protected thermometer.
Q = Pressure-constant of the unprotected thermometer.
d = Mean specific gravity of the water column above the thermometer, and is obtained from the chlorinity determinations and the temperatures.

The pressure-constant of the unprotected thermometer is the change in degrees in corrected reading caused by a change in pressure of 0.10 kilograms per square centimer. The constant is of the order of magnitude of 0.01 and is ascertained from the thermometer certificate which, however, usually gives the degree change in ten times the value of Q, or in other words, the degree change in readings per kilogram per square centimer change in pressure. In general, one meter in depth is equivalent to a change 0.01°C for the corrected readings.

Illustration

The corrected reading of the protected thermometer is 1.95°; of the unprotected thermometer 39.82°; the average density of the water, computed from chlorinity and temperature determinations made at twelve different

TABLE 1. - LENGTH IN METERS OF CABLE REQUIRED TO REACH CALCULATED DEPTHS AT CERTAIN WIRE ANGLES

Calculated depth (in meters)	Wire angle												
	20°	25°	30°	35°	40°	45°	50°	55°	60°	65°	70°	75°	80°
50	53	55	58	61	65	71	78	87	100	118	146	193	288
100	106	110	116	122	130	141	156	174	200	237	292	386	576
150	160	165	173	183	196	212	233	261	300	355	439	580	864
200	213	221	231	244	261	283	311	349	400	473	585	773	1152
250	266	276	289	305	326	354	389	436	500	592	731	966	1440
300	319	331	346	366	392	424	467	523	600	710	877	1159	1728
350	372	386	404	427	457	495	545	610	700	828	1023	1352	2016
400	426	441	462	488	522	566	622	697	800	946	1170	1546	2304
450	479	496	520	549	587	636	700	784	900	1065	1316	1739	2592
500	532	552	596	610	652	707	778	872	1000	1183	1462	1932	2880
550	585	607	635	672	718	778	856	959	1100	1301	1608	2125	3167
600	638	662	693	733	783	848	934	1046	1200	1420	1754	2318	3455
650	692	717	751	794	848	919	1011	1133	1300	1538	1901	2512	3743
700	745	772	808	855	914	990	1089	1220	1400	1656	2047	2705	4031
750	798	827	886	916	979	1060	1167	1307	1500	1774	2193	2898	4319
800	851	882	924	977	1044	1131	1245	1395	1600	1893	2339	3091	4607
850	904	938	982	1038	1109	1202	1323	1482	1700	2011	2485	3284	4895
900	958	993	1040	1099	1174	1273	1400	1569	1800	2129	2632	3478	5183
950	1011	1048	1097	1160	1240	1343	1478	1656	1900	2248	2778	3671	5471
1000	1064	1103	1155	1221	1305	1414	1556	1743	2000	2366	2924	3864	5759

Intermediate values can be calculated readily with a slide rule. On the K and E rule set the angle on the S scale (*using the left slanted* figures) opposite the desired depth. Read the length of cable opposite the S index.

depths, is 1.02550. The pressure constant as kilogram per square centimeter, is given as 0.1144. The true depth is

$$D = \frac{39.82 - 1.95}{0.1144 \times 1.02550} = \frac{37.87}{0.1173} = 3{,}228 \text{ meters}$$

According to Whitney (1957) the accuracy of thermometer depth determination is usually within 0.5 percent and is frequently 0.2 percent. Analysis of the factors affecting the accurancy is also given by Whitney.

2.3.1.5 Direct determination of density of sea water

Direct determination of salinity, usually by measuring the density, is sufficient and can be undertaken in cases where great variations occur, as in brackish water. The accuracy is usually in the range of $\pm$ 0.05 $^{o}/_{oo}$ of salinity.

There are several types of Temperature-Salinity-Depth (TSD) recorders. These instruments work on the principle of the changes of electrical conductivity with salinity and temperature. They record the TSD automatically on paper when the instrument is lowered into the water. They can be used only in brackish water and in the upper 100 m.

Salinity determinations are also made by refractometers (Figure 13), but only in brackish water, and the method needs considerable optical practice. The cheapest and simplest method to determine salinity in brackish water is with properly calibrated areometers (Figure 14), the reading of which can be converted to chlorinities and salinities by reference to Knudsen's tables, temperature having been measured.

2.3.1.6 Processing of oceanographic data

Most oceanographic data can be considered as indirect observations and need considerable corrections and processing before they are applied in solving certain problems. Some of the present standard methods are given in the following chapter. Again, the further application of these data is given in the synopsis on fisheries hydrography and in other manuals. The following notes have been extracted mainly from the following publications: LaFond, E.C. (1951) *Processing oceanographic data.* Washington, D.C., U.S. Navy Hydrographic Office. H.O. Pub. No. 614, and *Manual of oceanographic methods.* (1950) Nanaimo, B.C., Canadian Joint Commission on Oceanography, Pacific Oceanographic Group. (Mimeo)

Specific volume and specific volume anomaly

Specific volume (or volume per unit mass) *in situ* in the sea is expressed by the symbol $\alpha_{s,t,p,}$ where the subscripts indicate the salinity, temperature and pressure of the sample.

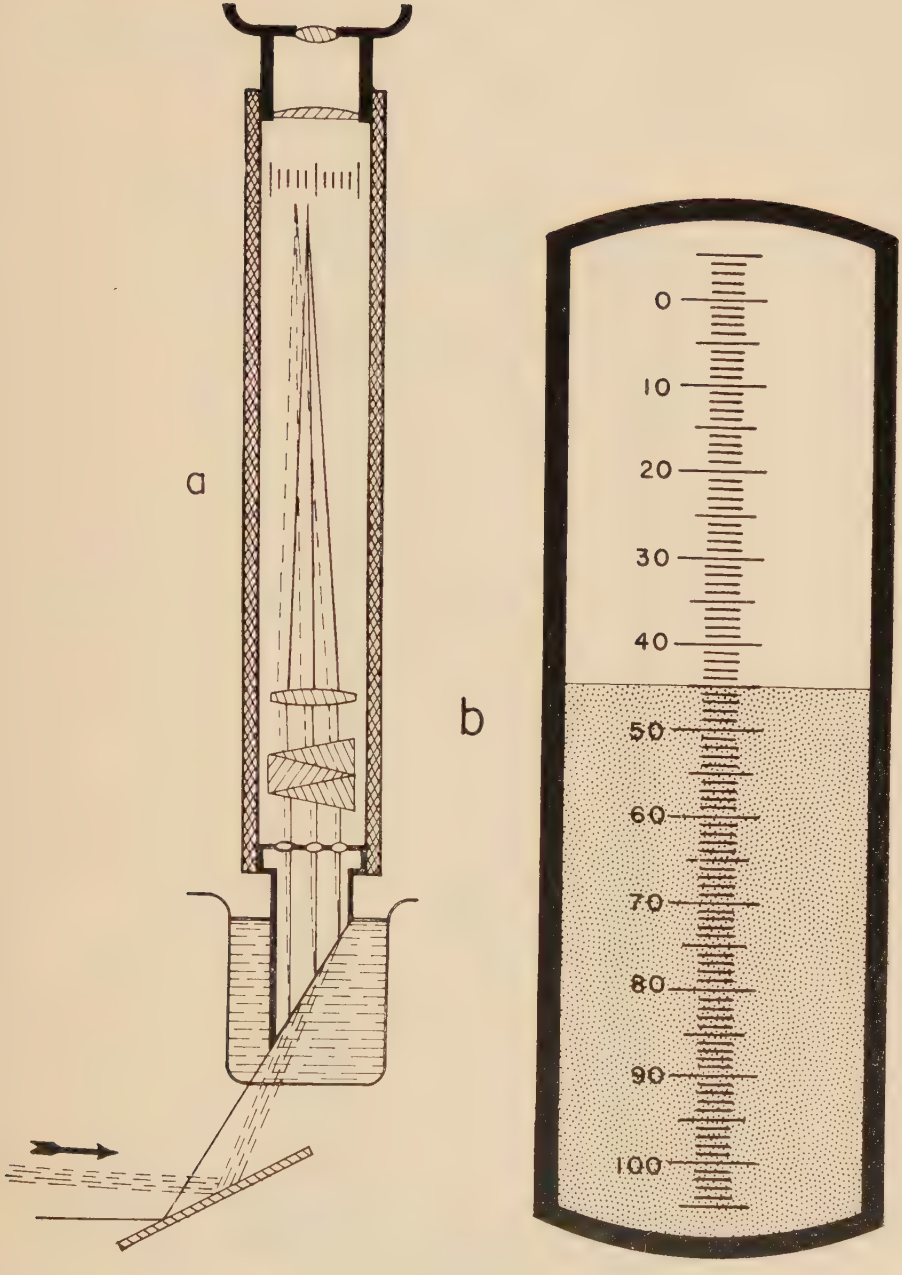


FIGURE 13. - Refractometer

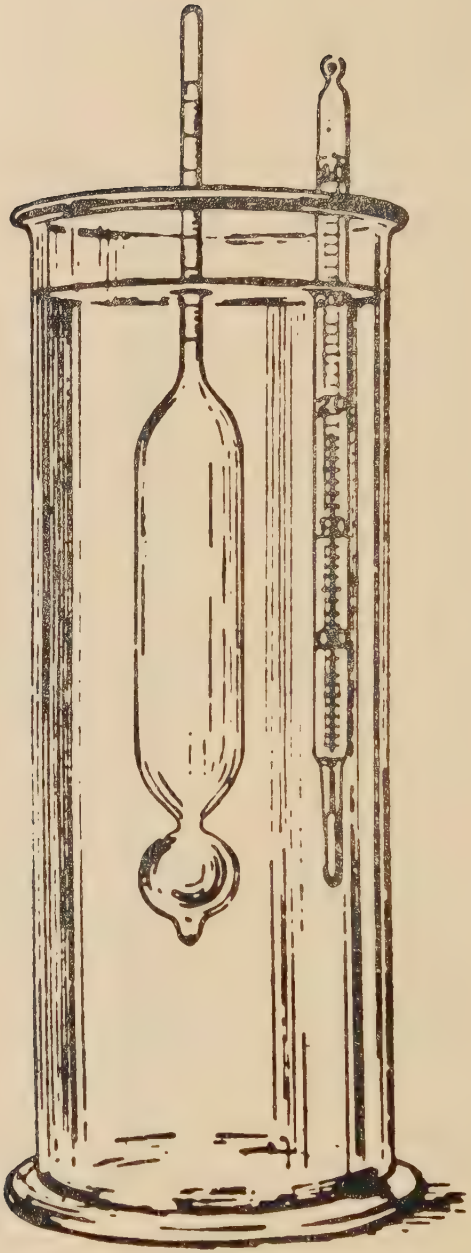


FIGURE 14. - Areometer

Specific volume *in situ* can be computed directly by the following equations developed by V.W. Ekman (Bjerknes and Sandström, 1910).

$$\alpha\, s, t, p = \alpha\, s, t, o - p\alpha\, s, t, o\ 10^{-9} \left(\frac{4886}{1 + 0.0000183\, p} - \right.$$

$$- [227 + 28.33\, t - 0.551\, t^2 + 0.004\, t^3] +$$

$$+ p\ 10^{-4} [105.5 + 9.50\, t - 0.158\, t^2] - 1.5\, p^2\, t\ 10^{-8} -$$

$$- \frac{\sigma o - 28}{10} [147.3 - 2.72\, t + 0.04\, t^2 - p\ 10^{-4} (32.4 - 0.87\, t +$$

$$+ 0.002\, t^2)] + \left(\frac{\sigma o - 28}{10} \right)^2 [4.5 + 0.1\, t - p\ 10^{-4} (1.8 -$$

$$\left. - 0.06\, t)] \right)$$

The above equation can be evaluated from values of temperature, t (°C); salinity, s (‰), or chlorinity, Cl (‰); and pressure, p (decibars), by means of the following expressions (Knudsen, 1901).

$$s = 0.030 + 1.8050\ Cl$$

$$\sigma o = -0.069 + 1.4708\ Cl - 0.001570\ Cl^2 + 0.0000398\ Cl^3$$

$$\sigma s, t, o = \Sigma t + (\sigma_o + 0.1324) [1 - A_t + B_t (\sigma_o - 0.1324)]$$

where,

$$\Sigma t = -\left[\frac{(t - 3.98)^2}{503.570} \right] \left[\frac{t + 283}{t + 67.26} \right]$$

$$A_t = t (4.7867 - 0.098185\, t + 0.0010843\, t^2)\ 10^{-3}$$

$$B_t = t (18.030 - 0.8164 + 0.01667\, t^2)\ 10^{-6}$$

and,

$$\alpha\ s, t, o = \frac{1}{\rho\ s, t, o} = \frac{1}{1 + 10^{-3}\ \sigma\ s, t, o}$$

The error in the specific volume calculated from the above expressions is believed to be ± 0.00001 for pressures of 1,000 decibars, and ± 0.0001 for 10,000 decibars.

The more practical method of computing specific volume is by expressing it as a known specific volume under given conditions, plus a series of correction terms for the dependent variables of temperature, salinity, and pres-

sure. These terms may be grouped, computed, and added as follows to give specific volume *in situ*:

$$\alpha_{S,\,t,\,p} = (\alpha_{35,0,0} + \delta_p) + (\delta_S + \delta_t + \delta_{S,\,t}) + \delta_{S,\,p} + \delta_{t,\,p} + (\delta_{S,\,t,\,p})$$

In the first two terms, $\alpha_{35,0,0}$ is a constant (0.97264) and δ_p represents the effect of pressure at standard salinity and temperature (35‰ and O°C). The sum of the two terms gives a standard specific volume:

$$\alpha_{35,0,0} + \delta_p = \alpha_{35,0,\,p}$$

The values of the standard term $\alpha_{35,0,\,p}$ are given in tables, e.g. LaFond, 1951.

The next three terms of the expansion depend only upon salinity and temperature, and are combined to form the single term $\triangle_{s,t}$; that is, $\delta_S + \delta_t + \delta_{S,t} = \triangle_{s,t}$. This temperature-salinity term of the anomaly of specific volume (discussed below) is found from values of temperature and salinity by means of tables or graphs, as will be illustrated presently (Sverdrup, 1933). If σ_t has already been computed, $\triangle_{s,t}$ may be found from the formula,

$$\triangle_{s,t} = 0.02736 - \frac{10^{-3}\,\sigma_t}{1 + 10^{-3}\,\sigma_t}$$

or by the tables (LaFond, 1951).

The salinity-pressure term, $\delta_{S,p}$, and temperature-pressure term, $\delta_{t,p}$ of the anomaly of specific volume are found from tables or graphs. The final term, $\delta_{S,\,t,\,p}$, is so small that it may be neglected.

The sum of the terms $\triangle_{s,\,t}$, $\delta_{S,\,p}$, and $\delta_{t,\,p}$, constitute the anomaly of specific volume from the standard, $\alpha_{35,\,0,\,p}$, and are designated by the single symbol δ. Thus,

$$\delta_S + \delta_t + \delta_{S,\,t} + \delta_{S,\,p} + \delta_{t,\,p} = \triangle_{s,\,t} + \delta_{S,\,p} + \delta_{t,\,p} = \delta$$

For current calculations, the variation in specific volume along an isobaric surface is required. Since pressure is constant along any given isobaric surface, the term δ_p is a constant as well as $\alpha_{35,0,0}$. It is sufficient, therefore, to calculate the specific volume anomaly, δ, since the standard term contributes nothing to variation in specific volume along an isobaric surface.

However, if the total specific volume *in situ* is desired, it is obtained by adding the standard term and the anomaly, $\alpha_{S,\,t,\,p} = \alpha_{35,0,\,p} + \delta$.

For calculating the anomaly, graphs or tables may be used, as mentioned above. The term $10^5\,\triangle_{s,\,t}$ is given in tables for values of temperature and salinity (e.g., LaFond, 1951). The other terms $10^5\,\delta_{t,\,p}$ and $10^5\,\delta_{S,\,p}$ are given in tables as well. Such tables have also been put in graphical form (Sund, 1926; Callaway, 1950).

To obtain sufficient accuracy the graphs should be of such a size that 1 inch along the co-ordinate axes represents 0.0001 of each of the terms of the anomaly or $0.1^{o}/_{oo}$ of salinity. A number of large charts are required to cover the normal range of the variables.

Density and "Sigma-T"

Density (or mass per unit volume) *in situ* is the reciprocal of the specific volume *in situ*:

$$\rho_{S,\,t,\,p} = \frac{1}{\alpha_{S,\,t,\,p}}$$

The density *in situ*, $\rho_{S,\,t,\,p}$, may be determined by first calculating the specific volume *in situ* from the equations and tables of the preceding pages and then taking the reciprocal. For example, if at a given salinity, temperature, and pressure the specific volume is 0.96996, the density

$$\rho_{S,\,t,\,p} = \frac{1}{0.96996} = 1.03097$$

Another way to express the density is by the symbol $\sigma_{S,\,t,\,p}$. By definition, $\sigma_{S,\,t,\,p} = 10^{3}\,(\rho_{S,\,t,\,p} - 1)$. Thus, if $\rho_{S,\,t,\,p} = 1.03097$, $\sigma_{S,\,t,\,p} = 30.97$. This expression has the advantage that the numerical value contains fewer digits and consequently is easier to handle.

It is common practice to abbreviate the expression $\sigma_{S,\,t,\,o}$ to only σ_t, which represents the density of water of given salinity and temperature at surface pressure. "Sigma-T" is widely used to describe the sea and has the significance that motion along σ_t surfaces involves little change in energy, and therefore, mixing of water masses tends to take place along these surfaces. By definition,

$$\sigma_t = 10^{3}\,(\rho_{S,\,t,\,o} - 1)$$

Thus, if $\rho_{S,\,t,\,o} = 1{,}02727$, $\sigma_t = 27.27$. In like manner, $\sigma_o = 10^{3}\,(\rho_{S,\,o,\,o} - 1)$.

σ_t depends only upon salinity and temperature, and may be found directly from values of these variables, either graphically or by means of tables. If $\triangle_{S,\,t}$ has been calculated, σ_t may be read directly from tables (LaFond, 1951). Other aids in the determination of σ_t are graphs.

If the temperature is 4.55°C. and salinity is $34.40\,^{o}/_{oo}$, σ_t will equal 27.27.

Several tables for σ_t, have been compiled by various people including LaFond (1951), McEwen (1929), Matthews (1932), Fleming (1939), Ennis (1944), and Bumpus and Martineau (1948). These tables are based on Knudsen's equations given on the preceding pages.

Relative currents

The current along an isobaric surface is essentially a function of the geopotential (or dynamic) slope of the isobaric surface. If, at some depth, motion may be assumed negligible and an isobaric surface essentially level, the dynamic slope of an upper isobaric surface may be found from the variation of specific volume along the isobaric layer. Thus the current at the upper surface relative to any possible current at the lower surface is determined.

For each oceanographic station of a network of stations, the dynamic thickness of the isobaric layer may be calculated by means of the hydrostatic equation,

$$D_2 - D_1 = \int_{p_1}^{p_2} \alpha \, dp$$

where,

$D_2 - D_1$ = dynamic thickness of the isobaric layer,
α = specific volume,
dp = pressure interval.

Since $\alpha = \alpha_{35, 0, p} + \delta$, the total dynamic thickness of the layer may be considered composed of the dynamic thickness of the layer of standard specific volume from standard. Thus,

$$D_2 - D_1 = \int_{p_1}^{p_2} \alpha_{35,\ 0,\ p} dp + \int_{p_1}^{p_2} \delta \, dp =$$

$$= (D_2 - D_1)_{\text{standard}} + \triangle D.$$

The dynamic thickness of the standard layer is the same at every station. Therefore the differences in dynamic height between stations are completely given by the differences in the increments, $\triangle D$, and it is only necessary to calculate $\triangle D$ at each station, using the formula $\triangle D = \int_{p_1}^{p_2} \delta \, dp$.

In practice, meters of depth are substituted for decibars of pressure in the equation. The insignificant error in $\triangle D$ introduced by this substitution is negligible, amounting to 1 percent or less.

Procedure in computing $\triangle D$ at each station is as follows. The specific volume anomaly, δ, at each depth is calculated by one of the methods previously outlined. The mean specific volume anomaly, $\bar{\delta}$, for each depth interval may be determined by averaging the two bounding values. Multiplying this mean value, $\bar{\delta}$, by the depth interval (which corresponds essentially to the pressure interval between depths) gives the anomaly of dynamic height, $\triangle D$, for each small depth (or pressure) layer. The required total $\triangle D$ for each station is obtained by adding the anomalies of dynamic height, $\triangle D$, from the selected reference level of no motion to the level at which relative currents are to be computed.

The final step in computing the current passing between two stations is to equate the forces acting along the sloping isobaric surface between stations, and solve for the velocity. The force of gravity acting downslope is expressed by the difference in the anomalies of dynamic height at the two stations divided by the distance between stations. Since the computation of $\triangle D$ was based upon pressure in decibars, rather than the standard unit centibars, a factor of 10 is necessary to convert the expression to meter-ton-second units. Equating this force to the expression for the Coriolis force acting upslope gives

$$\frac{10\ (\triangle D_A - \triangle D_B)}{L} = V 2\ \omega \sin \varnothing$$ (Sandström and Helland-Hansen, 1903), where,

$\triangle D_A - \triangle D_B$ = difference in the anomalies of dynamic height at stations A and B, in dynamic meters,

L = distance between stations in meters,

V = relative current velocity normal to a line joining the two stations, in meters per second,

ω = angular velocity of the earth, equal to 0.729×10^{-4} radians per second,

$\varnothing$ = mean latitude between stations.

Solve the equation for the velocity: $V = \dfrac{10\ (\triangle D_A - \triangle D_B)}{L\ 2\ \omega \sin \varnothing}$

To simplify the computation of velocity in meters per second, the factor $\dfrac{10}{L\ 2\ \omega \sin \varnothing}$ is given in tables for unit values of L and for each degree of latitude. Conversion factors are also given in tables for various units of V and L. There are graphical aids in the calculation of current velocity from dynamic height differences (LaFond, 1951).

The usual graphical way not only of measuring but also presenting current data for analysis is by the construction of charts showing the dynamic topography of one or more isobaric surfaces relative to a reference surface, which is assumed to be level. The anomaly of dynamic height, $\triangle D$, between the reference surface and the selected isobaric surface above is plotted on a base chart at each oceanographic station, and contours of equal values of dynamic height anomaly are drawn.

Since the force of gravity acts downslope normal to the contours, and the balancing Coriolis force is always normal to the velocity, it follows that the current flows along the contours of dynamic topography. The surface slopes upward to the right of the current in the northern hemisphere, to the left of the current in the southern hemisphere.

When the contours are drawn at equal intervals of dynamic height anomaly, the velocity of the current is inversely proportional to the distance between contours. An insert graph is normally given on the chart to relate dynamic height contour spacing to current speed. Charts showing the dynamic topography of an isobaric surface relative to a lower isobaric surface thus not only present a complete picture of motion at the upper surface relative to any motion at the lower surface, but eliminate the need for numerical calculation of the components of currents between stations from dynamic height differences.

Certain limitations to the accuracy of the current calculations outlined above should be borne in mind: (1) Currents deduced are relative to any unknown current at the reference level rather than absolute values. (2) Accelerations have been neglected; if currents are changing, the results of the calculations are less valid. (3) Frictional forces have been neglected. (4) Observations taken at different times at the different stations have been assumed simultaneous. In some areas the influence of internal waves (LaFond, 1949) and tidal influence on dynamic height are taken into account. These limitations may, however, be largely offset by the familiarity with a region which comes with repeated observations (provided conditions are quasi-permanent).

2.3.1.7. Turbidity measurements

Measures of turbidity are an indication of the amount of suspended matter, including plankton, in the sea water. Changes of turbidity often indicate changes of water masses and convergence lines.

Turbidity measurements are made either visually or with optical instruments. The white, 30-35 cm diameter, Secchi disk is used for visual estimates. It is lowered into the water, on the shadow side of the vessel, attached to a line marked in meters or feet. The depth at which the disk disappears from sight is recorded. The disk should be moved slowly up and down at this depth in order to determine the exact depth of disappearance. The depth is usually converted into extinction coefficients: $X = 1.7/D$ where X = extinction coefficient; D = maximum depth of visibility of Secchi disk (in m).

The extinction coefficient can also be measured with electrical extinction meters lowered into the water (Figure 15). These instruments have an electric light in one end and a photocell at a distance of 60 cm - 2 m at the opposite end. The readings of the photocell are converted either into the percentage of light intensity as compared with clean water, or into an extinction coefficient. The latter should be recorded. These instruments need careful attention and special study. For example, the light source must be constant and the window clean and dry on the inside; drying chemicals (e.g., silica gel) are used for this purpose.

Quantitative and qualitative study of suspended matter in sea water can also be made by taking water samples from different depths. The samples must be analyzed immediately on arrival on board. For a more detailed description of these methods with photometers, spectrophotometers or more often with Tyndall's apparatus (Figure 16) see references at the end of this Section.

← FIGURE 15. - Plan of the transparency-meter

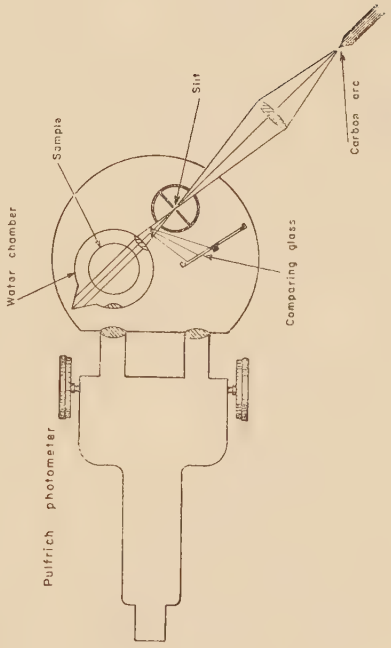


FIGURE 16. - Tyndall meter →

FORM 3. - PRIMARY OCEANOGRAPHIC DATA SHEET

(a) Cruise	(b) Station	(c) Latitude	(d) Longitude	(e) Wind force	(f) Sonic depth	(g) Color of the sea	(h) Cast	(i) Wire angle	(j) Start (GCT)	(k) Messenger		
										(l) Down (GCT)	(m) Up (GCT)	(n) In (GCT)

(o) Vessel (name)	(p) Date (GCT)	(q) Sea	(r) Bottom type	(s) Trans-parency	(t) BT Slide No.	(u) Observer

1 Des. Depth m	2 Meter wheel	3 Thermo-metric depth	4 Wire depth	5 Sample bottle No.					6 Sampler (Nansen bottle) No.	7 Thermom-eter Left		8 Thermom-eter Right		9 Remarks
				5.1 Cl °/₀₀	5.2 02	5.3 PO 4	5.4	5.5		7.1 Main	7.2 Aux.	8.1 Main	8.2 Aux.	

Notes on Form 3. - Primary oceanographic data sheet

This sheet is completed (with a carbon copy) for every hydrographic station at which water samples from below surface are taken.

(*c*)/(*d*). Instead of latitude and longitude a descriptive position or a number or letter for routine stations can be given in coastal waters if the exact position of the station is clearly indicated on the chart and in the Cruise and Station log, but only provided these other records are easily accessible to those using this sheet.

(*e*). Give wind force only. Other meteorological data are entered in the meteorological data sheet, which is usually kept on the bridge.

(*f*). Give the depth obtained as with the echo-sounder (or by other sounding). If this is not possible, enter the depth as indicated on the sea chart.

(*g*). State the color of the sea according to the Forel scale.

(*h*)/(*i*)/(*j*)/(*k*)/(*l*)/(*m*)/(*n*). Give the number of hydrographic casts, wire angle before sending the messenger for closing the bottles and the times for starting the cast, when messenger is sent down, when the heaving up is started and when all bottles are in.

(*q*). Give the state of the sea, coded.

(*r*). Give the coded description of sediment or type of bottom if sample obtained, or the type of bottom if otherwise ascertained (e.g., from sea charts, sediments fastened on weight, etc.).

(*s*). State the transparency, as obtained by the Secchi disk.

2. Give the meter wheel readings when lowering the cast.

3. Thermometric depth as determined later from the difference between the unprotected and protected temperature readings.

4. Wire depth as determined from the meter wheel reading and wire angle. (See Table 1.)

5. Give the numbers of the sample bottles.

6. Give the numbers of Nansen bottles (or other water samplers used).

7/8. Enter the readings of the thermometers.

9. Remarks should include any misbehavior of thermometers and other items of interest. The numbers of salinity boxes, amount of roll of vessel, etc., should also be noted here.

FORM 4. - OCEANOGRAPHIC SUMMARY SHEET

(*a*) Vessel .. ..(*b*) Station (*c*) Date-Time .. .. to .. . .

(*d*) Latitude . .....(*e*) Longitude ....(*f*) Depth .....(*g*) Observer .. .

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
Serial	Calc.	Observed		Interpolated													
No.	P	T°C	S°/₀₀	D	T°C	S°/₀₀	σ_o	σo-σt	σt	$\Delta s, t$	$\delta t, p$	$\delta s, p$	δ	δ	Δ D	Σ D	

Notes on Form 4. - Oceanographic summary sheet

Make entries in the heading as indicated, using the name of the vessel from which the samples were taken and the serial station number. Indicate time zone on which times are based (Z for Greenwich; + values for zones west, and — values for zones east of Greenwich). Report latitudes and longitudes in degrees and minutes, with decimal fractions of a minute when such are significant. Report depths in meters. The columns have the following significance:

1. Serial number of observation.

2. Depth, calculated using meter wheel readings, wire angle and protected and unprotected thermometer readings.

3. Temperature for depth given in column 2 as obtained from protected thermometer, fully corrected.

4. Salinity for depth given in column 2.

5. Standard depths for purposes of computation.

6. Temperatures at standard depth as obtained by interpolation from temperature vs. depth curve based on values given in columns 2 and 3.

7. Salinities at standard depths as obtained from salinity vs. depth curve based on values given in columns 2 and 4. (The use of chlorinities in preference to salinities awaits expansion of suitable tables for use in interpolation.)

8. As normally defined $O_o = (C_o - 1)\ 10^3$ where C_o is the density of the water of the given chlorinity at 0°C under atmospheric pressure. In this column, however, the factor 10^5 is used rather than 10^3 in order to drop the decimal point. Obtain from Knudsen's tables.

9. $D = O_o - O_t$ as obtained from Knudsen's tables or expansion of same (cf. expanded table of Thompson and Robinson). As in column 8 the factor of 10^5 is used rather than 10^3 in order to drop the decimal point.

10. $O_t = (\sigma_{s,\,t,\,o} - 1)10^3$ where $\sigma_{s,\,t,\,o}$ is the density of the water of given salinity, and t_0C under atmospheric pressure. Factor of 10^5 rather than 10^3 is used to permit dropping decimal point. O_t is obtained from columns 8 and 9 or preferably directly from columns 6 and 7 where suitable tables are available to cover temperature-salinity range [see Donald J. Matthews. (1932) *Tables of the determination of density of sea water under normal pressure, Sigma-t.* Cons. int. Explor. Mer. 59 p.; and E.C. LaFond. (1951)

Processing oceanographic data. U. S. Navy Hydrographic Office. 114 p. H.O. Pub. No. 614].

11. Values of $10^5 \triangle_{s,t}$ as obtained from O_t, column 10, using Table III, appendix, p. 1055 of *The oceans.*

12. 10^5 $C_{t,p}$ as obtained from Tables Va and Vb of *The oceans* (appendix, p. 1058-1059). (For expansion see LaFond, 1951.)

13. 10^5 $\delta_{s,p}$ as obtained from Tables IVa and IVb of *The oceans* (appendix, p. 1056-1057). (For expansion see LaFond, 1951.)

14. 10^3 δ as obtained by applying pressure corrections in columns 12 and 13 to base values of $10^5 \triangle_{s,t}$ given in column 11.

15. Means of 10^5 between successive depths as obtained from column 14.

16. Geopotential anomaly between successive isobaric surfaces expressed in dynamic meters. These values are the product of means of 10^5 (column 15) and corresponding depth increments obtained from successive depth differences in column 5.

17. Cumulative anomalies of dynamic depth (dynamic meters) of the corresponding isobaric surfaces (column 5) summed by adding successive values in column 16. The depth of any isobaric level in dynamic meters can be obtained by adding the anomaly (column 17) to the corresponding values for standard isobaric reference levels given in *The oceans*, Table II, appendix, p. 1054.

Note: For bibliographical references to the subject matter contained in this fascicule *see* 2.3.5 References, at end of Fascicule 7.

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MANUAL OF METHODS IN FISHERIES BIOLOGY

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T. LAEVASTU

Fascicule 6

Section 2. Observations on the physical and chemical environment

2.3.2 Chemical analyses of water

FOOD AND AGRICULTURE ORGANIZATION OF THE UNITED NATIONS
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2.3.2 Chemical analyses of water

2.3.2.1 Introduction

Only a few major water analysis methods will be described in condensed form in this Section. When a detailed description of other analyses or tests is necessary, the methods employed can be found in other standard textbooks, such as those listed in Section 1.2.4 (e.g., Strickland and Parsons, 1960).

The chlorinity analysis is one of the most important analyses in the marine environment. The results are used for deriving other important data, e.g., the salinity and density of the water, etc., and in turn, these data are used for the characterization of the water masses, for tracing their origin, movements and history, mixing, etc. In certain cases, the salinity has a direct influence on the distribution of fish, and more especially on the buoyancy and survival of pelagic fish eggs and fry.

In the marine environment, low oxygen content very seldom becomes critical for the fish, except in certain locations in the tropics (the subsurface oxygen minimum layer), and close to the bottom in badly aerated depressions. The oxygen data in the marine environment are used together with the salinity data for the characterization of water masses and for the determination of their physical and biological history.

Phosphates, nitrates and silicates are important nutrient salts in the sea water where they are at times exhausted, thereby limiting organic production. The amounts of these nutrient salts present in certain areas and at certain seasons also give an indication of the fertility of the areas and of the biological processes taking place. Because of the relatively small variations of the chemical properties in sea water with distance and time, the required accuracy of analysis in the marine environment is considerably higher than in fresh water.

In fresh water the chemical analysis will usually be restricted to the tests of oxygen, carbon dioxide, phenolphthalein alkalinity, methylorange alkalinity and pH. The carbon dioxide and pH in the marine environment never become limiting factors for the organic productin, but are very often limiting factors in fresh water.

The exact number of chemical stations on a lake depends upon the type of lake and is left to the discretion of the analyst. On very small shallow lakes a surface and bottom sample might be entirely sufficient; on other lakes several samples between top and bottom may be needed to determine the chemical condition. On a larger lake, with many bays and depressions, many stations will be needed to cover all the major areas.

2.3.2.2 Obtaining water samples

To extract water samples a rubber tube with a glass tube about 15 cm long in one end is fastened to the tap of the water sampler; the air valve at the upper end of the sampler is then opened and water drawn off. The samples

for oxygen determination (and for other gas analyses) are taken first, followed by those for phosphate and salinity determination. All receiving bottles must be rinsed with a little of the sample water, but care should be taken not to use much water for this purpose when many samples are required.

Samples for oxygen determination are run into 250-ml dark bottles fitted with special glass stoppers. The bottles must be numbered and their volumes known with accuracy. To draw off samples for oxygen test, the glass tube should be very close to the bottom of the receiving bottle and about 100 ml of the water run in slowly, care being taken that no bubbles of air enter the water. The glass tube is then slowly lifted while the water is still running. The glass stopper is inserted when the bottle is full, taking care there are no air bubbles under the stopper. When all samples have been drawn off, potassium iodide and manganese sulphate (or chloride) solutions are added to the oxygen samples. After half an hour sulphuric acid is added and the sample is shaken.

The samples for phosphate, silicate and nitrate determination are brought to laboratory temperature and frequently the analysis is made on board. If the silicate determinations cannot be done on board immediately after the arrival of the samples, they should be stored in polythene bottles. All special samples, taken to determine minor constituents or trace elements used by micro-organisms, should be so preserved that biological action does not continue in the sample and that the suspended matter does not decompose. Special instructions are necessary for this, depending on the nature of the analyses, although in general a few drops of chloroform are used as preservative. If there is a deepfreezer available on board, the phosphate samples are frozen.

Samples for chlorinity titration are run into 200 - 300-ml bottles fitted with attached stoppers with rubber washers. The bottles should be filled almost completely, leaving only 5 - 10 ml space under the stopper to allow for expansion. If greater space were left, evaporation and change in chlorinity might take place.

2.3.2.3 DETERMINATION OF CHLORINITY AND SALINITY [to follow]

2.3.2.4 DETERMINATION OF DISSOLVED OXYGEN [to follow]

2.3.2.4.1 *Modified Winkler method* [to follow]

2.3.2.4.2 *Rapid estimation of dissolved oxygen in fresh water*

EQUIPMENT

125-ml glass-stoppered bottles
250-ml Erlenmeyer flasks, marked at 100-ml capacity
5-ml pipette

If Barnes dropping bottles with plastic caps cannot be obtained for the first three reagents listed below, ordinary medicine droppers graduated to 0.5 ml can be used with standard bottles as described below.

REAGENTS

Manganous sulfate ($MnSO_4$)
Alkaline iodide
Concentrated sulfuric acid (H_2SO_4)
N/40 sodium thiosulfate ($Na_2S_2O_3$)
Starch solution or thiodine solution

The above chemicals, except the sodium thiosulfate ($Na_2S_2O_3$) can be put in Barnes dropping bottles. If these bottles are not available the manganous sulfate and alkaline-iodide solutions should be stored in rubber-stoppered bottles, the sulfuric acid in glass-stoppered bottles. The sodium thiosulfate solution is usually kept in amber colored glass-stoppered bottles. It should be made up fresh every two weeks or at most three weeks.

PREPARATION OF REAGENTS

Manganous sulfate solution (for O_2 determination)

Dissolve in distilled water and make up to 1 liter one of the following quantities:

480 g $MnSO_4.4H_2O$, or

400 g $MnSO_4.2H_2O$, or

364 g $MnSO_4.H_2O$

Alkaline-iodide reagent

Dissolve in distilled water and make up to 1 liter one of the following combinations:

500 g NaOH and 135 g NaI, or

500 g NaOH and 150 g K I, or

700 g KOH and 135 g NaI, or

700 g KOH and 150 g K I.

Sulfuric acid, concentrated

Specific gravity, 1.83 to 1.84
About 36 N

Sodium thiosulfate solution, N/40 (0.025N)

Dissolve 6.205 g $Na_2S_2O_3$-$5H_2O$ in freshly boiled and cooled distilled water and make up to 1 liter. Add 5 ml chloroform ($CHCl_3$) or 0.4 g NaOH per liter as a preservative. Store in brown bottle. Make up a fresh solution every two or three weeks.

Starch solution

Grind up 5 g of potato or arrowroot starch in a small quantity of distilled water. Pour the emulsion into 1 liter of boiling water, stir and leave to settle overnight. Decant the clear portion. Add 1.25 g of salicylic acid as a preservative or a few drops of toluene.

PROCEDURE

The first four steps must be performed in the field immediately after collecting the sample from the desired depth by use of a water sample bottle.

1. Collect sample into 125-ml glass-stoppered bottle by gently flowing water into bottle without any splashing or bubbling. Allow water to overflow at least 20 seconds after it is filled.
2. Add 0.5 ml manganous sulfate ($MaSO_4$) and 0.5 ml of alkaline iodide (KI-KOH) well below the surface. Restopper and mix by inverting bottle several times, being sure stopper is held in place.
3. Allow precipitate that forms to settle.
4. When settled, remove stopper and add 0.5 ml of concentrated sulfuric acid (H_2SO_4). Restopper and mix. If sample is adequately stoppered it may now stand several hours without change in oxygen content.
5. Rinse an Erlenmeyer flask with a small amount of the sample, then fill to the 100-ml line (or transfer 100 ml, using a graduated cylinder for measuring). Titrate with 0.025 solution (N/40) of sodium thiosulfate ($Na_2S_2O_3$), rotating sample to ensure mixing, until color becomes a pale yellow.
6. Add starch solution to produce blue color, or if thiodine is used add enough powder to produce the blue color.
7. Continue titration until blue color first disappears.
8. Record total amount of sodium thiosulfate used and ignore any return of blue color.

CALCULATIONS

To express results in parts per million (ppm) of dissolved oxygen, multiply ml of $Na_2S_2O_3$ used by 2.

CONVERSIONS

1. 1 part per million (ppm) = 1 milligram (mg) (0.001 g) per liter
2. ppm $\times$ 0.698 = milliliters (ml) per liter
3. ml per liter $\times$ 1.43 = ppm or mg/l.
4. To express results as percentage of saturation, determine from Table 1 the saturation value at sea level for the temperature of the water when the sample was collected.

2.3.2.5 Determination of phosphorous compounds [to follow]

2.3.2.6 Determination of nitrogen compounds [to follow]

2.3.2.7 Determination of carbon dioxide, alkalinity and pH in fresh water

2.3.2.7.1 *Carbon dioxide estimation*

EQUIPMENT

100-ml Nessler tube (or 100-ml graduated cylinder)
5-ml pipette

REAGENTS

Phenolphthalein indicator
N/44 sodium hydroxide (NaOH)

PROCEDURE

1. Draw 100 ml of the sample into a Nessler tube or tall graduate cylinder being careful not to splash sample since agitation releases carbon dioxide.
2. Add 10 drops of phenolphthalein indicator.
3. If sample turns pink, record as 0.0 CO_2.

TABLE 1. - SATURATION VALUES OF OXYGEN IN FRESH WATER AT STANDARD PRESSURE

Temp. °C	Oxygen ppm or mg/l	Temp. °C	Oxygen ppm or mg/l	Temp. °C	Oxygen ppm or mg/l
0	14.62				
1	14.23	11	11.08	21	8.99
2	13.84	12	10.83	22	8.83
3	13.48	13	10.60	23	8.68
4	13.13	14	10.37	24	8.53
5	12.80	15	10.15	25	8.38
6	12.48	16	9.95	26	8.22
7	12.17	17	9.74	27	8.07
8	11.87	18	9.54	28	7.92
9	11.59	19	9.35	29	7.77
10	11.33	20	9.17	30	7.63

Then multiply this value by the appropriate factor from the next table (Table 2) based upon the altitude of the body of water sampled.

TABLE 2. - CORRECTION FACTORS FOR OXYGEN SATURATION VALUES ACCORDING TO ALTITUDE IN METERS

	0	100	200	300	400	500	600	700	800	900
0	1.000	0.987	0.975	0.963	0.951	0.939	0.928	0.916	0.904	0.893
1000	0.883	0.872	0.862	0.851	0.841	0.830	0.820	0.809	0.800	0.791
2000	0.782	0.772	0.763	0.754	0.745	0.737	0.728	0.718	0.709	0.701
3000	0.693	0.686	0.678	0.670	0.662	0.654	0.646	0.638	0.632	0.624
4000	0.617									

The percentage saturation (excluding hydrostatic pressure) of the sample is then equal to

$$\frac{\text{observed } O_2 \text{ content}}{\text{saturation value at particular temperature and altitude}}$$

4. If sample remains clear, titrate with N/44 sodium hydroxide (NaOH), until weak pink color remains for a minimum of 30 seconds.

5. Record number of milliliters of sodium hydroxide used.

CALCULATIONS

1. Ten times the number of ml of N/44 NaOH used equals the amount of carbon dioxide in parts per million.

2. Conversions from ml/l to ppm:

Multiply	*By*	*To obtain*
ppm of CO_2	0.506	ml/l
ml/l of CO_2	1.98	ppm

2.3.2.7.2 *Alkalinity determination*

EQUIPMENT

250-ml Erlenmeyer flask
5-ml pipette

REAGENTS

Phenolphthalein indicator
Methyl-orange indicator
N/50 sulfuric acid

PROCEDURE

1. Draw 100 ml of sample water into flask or bottle.

2. Add 4 drops of phenolphthalein indicator.

3. If sample remains clear, record as 0.0 ph-th (Phenolphthalein) alkalinity, and proceed with step 5.

4. If sample turns pink, titrate it with 0.02 N (N/50) sulfuric acid (H_2SO_4) from a burette, until pink color just disappears. Titration should be done against a white background for better color perception. Record amount of acid used as *P*.

5. To same sample, add 4 drops of methyl-orange indicator.

6. If sample turns orange (often expressed as salmon color), record as 0.0 methyl-orange alkalinity.

7. If sample becomes yellow, titrate with 0.02 N (N/50) sulfuric acid until it turns faint orange. Sample should be rotated after each few drops to insure mixing. Record amount of acid used as *M*.

CALCULATIONS

1. *Symbols and terms*

P = No. of ml N/50 H_2SO_4 used in titration with phenolphthalein

M = No. of ml N/50 H_2SO_4 used in titration with methyl-orange

T = Sum of P and M; i.e., the total number of ml N/50 H_2SO_4 used in the total titration

In the calculation that follows one uses only P and T. From these one can determine and express in parts per million of calcium carbonate either:

(i) phenolphthalein alkalinity = $P \times 10$

(ii) total alkanility (also known as methyl-orange alkanility) = $T \times 10$

2. *Conversions and interpretation of alkalinity relationships*

(*a*) Conversion to SBV [1]

To convert the total or methyl-orange alkalinity (as expressed in ppm of calcium carbonate) into a value equivalent to the SBV used by some workers, divide it by 50.

To convert SBV into the total or methyl-orange alkalinity (as expressed in ppm of calcium carbonate), multiply it by 50.

(*b*) Interpretation of alkalinity relationships

When desired, one can make further differentiations of alkalinities due to hydroxide (OH), normal carbonate (CO_3) and bicarbonate (HCO_3), using Table 3 below for mathematical conversion of results.

---

[1] SBV (*Säurebindungsvermögen*) known variously as acid combining power, alkaline reserve, etc., is expressed simply as the total number of ml of N/10 HCl or H_2SO_4 required to titrate 100 ml of a water sample using methyl orange as an indicator.

According to this scheme:

(i) Carbonate alkalinity is present when the phenolphthalein alkalinity is not zero but is less than the total alkalinity.

(ii) Hydroxide alkalinity is present if the phenolphthalein alkalinity is more than one half the total alkalinity.

(iii) Bicarbonate alkalinity is present if the phenolphthalein alkalinity is less than one half the total alkalinity.

TABLE 3. - CONVERSION OF ALKALINITY VALUES

Result of titration	Alkalinities expressed as ppm of calcium carbonate		
	Hydroxide	Carbonate	Bicarbonate
$P = O$	0	0	$T \times 10$
$P < \frac{1}{2} T$	0	$2P \times 10$	$(T - 2P) \times 10$
$P = \frac{1}{2} T$	0	$2P \times 10$	0
$P > \frac{1}{2} T$	$(2P - T) \times 10$	$2(T - P) \times 10$	0
$P = T$	$T \times 10$	0	0

2.3.2.7.3 *pH determination*

TYPES OF pH EQUIPMENT

Generally there are two kinds of methods for measuring the pH (hydrogen ion concentration) of the water: colorometric and electrometric.

Colorometric methods depend on the addition of sensitive indicator solutions to the sample and making comparison with a set of standard colors of known pH values. There are also available sensitized papers which when dipped in the sample water change color. This color is then checked against the standards for the pH value.

Electrometric methods are also of several types depending on the apparatus purchased. Usually this method is confined to laboratory work because of the rather delicate nature of the electric equipment, although some companies do have portable battery-operated field equipment.

PROCEDURE

The procedure for making the pH determination is given with each set of simple optical instruments (color comparator) for this purpose. Follow the directions as given with the set available to the worker.

REAGENTS

Phenolphthalein indicator

Dissolve 5 g of high-quality phenolphthalein in 1 liter of 50 % ethyl alcohol; then add N/50 (0.02N) NaOH dropwise until a faint pink color appears. (Prepare the 1 liter of 50 % alcohol by diluting 526 cc of 95 % alcohol to 1 liter with boiled distilled water.)

Methyl-orange indicator

Dissolve 0.5 g of high-quality methyl orange in 1 liter of distilled water. Keep in dark glass bottle.

Sulfuric acid, N/50 (0.02N)

Transfer 10 ml concentrated H_2SO_4 to a volumetric flask and make up to 1 liter with distilled water. The resulting solution is approximately 0.36N. To make up a N/50 solution from this stock solution, transfer 55.56 ml to a volumetric flask with a burette and make up to 1 liter.

To standardize, place 20 ml N/44 Na_2CO_3 (see below) in a casserole or Erlenmeyer flask over a white background and add 5 drops of methyl-orange indicator. Titrate with the dilute acid until the color begins to change from yellow to red. The normality factor of the N/50 acid is the number of ml of acid used divided into 22.73.

Sodium carbonate, N/44

Heat chemically pure sodium carbonate in an open casserole over a bunsen burner for 1/2 hour to convert any bicarbonate present into carbonate. When cool weigh out 1.205 g and dissolve in recently boiled distilled water, making up to 1 liter. This gives a N/44 solution. Because alkaline solutions such as these rapidly absorb CO_2 from the air thereby altering their normality, they should be kept tightly stoppered, or in bottles having CO_2 traps.

Note: For bibliographical references to the subject matter contained in this fascicule *see* 2.3.5 References, at end of Fascicule 7.

FORM 1. - FRESH WATER ANALYSIS LOG

Lake or stream .....

Station number	Date	Time	Air temp.	Sky	Wind dir. vel.	Preceding weather	Water color	Secchi disk

Depth meters	Temper-ature	Bottle number	Thio cc.	Factor	O_2 ppm	CO_2	ph-th	MO	pH

Price: $0.50 or 2s 6d

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Fascicule 7

Section 2. Observations on the physical and chemical environment

2.3.3 Observations of sea surface
2.3.4 Explanation of terms
2.3.5 References

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2.3.3 **Observations of sea surface**

Adequate observations of sea surface can be made simply, without instruments, provided consistency and accuracy of description are maintained. This can be effected by careful use of the appropriate meteorological and sea-surface codes.

2.3.3.1 Waves

Wind waves and swell should be observed and recorded separately. They are usually superimposed and a certain amount of practice is necessary to distinguish between them. The following notes will be found of assistance.

Sea (*wind waves*) — Waves caused by wind in the immediate neighborhood at the time of observation. The direction of the waves is usually the same as that of the wind, except when the wind changes direction quickly. The wind-wave period is usually smaller than that of the swell; also wind waves are steeper.

Swell — A system of waves created by winds at a distance from the point of observation. The period is long and the wave round.

The wave characteristics which should be used for reporting are:

Length — The horizontal distance between successive crests or troughs (equal to the wave period multiplied by the wave speed).

Period — The time between the passage of two successive wave crests past a fixed point (equal to the wave length divided by the wave speed).

Speed — The distance travelled by a wave in unit time (equal to the wave length divided by the wave period).

Height — The vertical distance between trough and crest.

The period, direction and height can easily be observed. Period can be determined by noting some small object or patch of foam on the surface, and with a stop watch, timing the interval between its appearance on the crest of one wave and its appearance on the crest of the next wave. Many observations should be made of the same object and the period recorded as the mean calculated by dividing the total time, measured with the stop watch, by the number of appearances of the object on the wave crests. The direction from which the waves come can be ascertained by adding or subtracting 90° to or from the compass bearing of the crests. To estimate the height of small waves the observer should be close to the sea surface and preferably amidships. To estimate the height of high waves the observer should climb up

and down the mast and record the height of his eye from sea level when he sees the crest of the wave relative to the horizon. The average height of the larger well-formed waves should be recorded. This is, of course, a very rough method.

When making simple wave observations from coastal stations care must be taken to choose a site from which shallowness and/or reflection does not give false impressions of the waves. For such observations special wave recorders are available, but need experts to install them and special instruction for interpretation of their records. A graduated line at the end of a pier or an anchored floating buoy will give reasonably accurate visual measures of both wave height and period. The codes for recording sea and swell are set out in Tables 1 and 2.

TABLE 1. - CODE FOR REPORTING SEA CONDITIONS

Code figure		Height	
		meters	feet (approx.)
0	Calm-glassy	0	0
1	Calm-rippled	0 - 0.1	0 - 1/3
2	Smooth-wavelets	0.1 - 0.5	1/3 - 1 2/3
3	Slight	0.5 - 1.25	1 2/3 - 4
4	Moderate	1.25 - 2.5	4 - 8
5	Rough	2.5 - 4	8 - 13
6	Very rough	4 - 6	13 - 20
7	High	6 - 9	20 - 30
8	Very high	9 - 14	30 - 45
9	Phenomenal	over 14	over 45

The following phenomena should also be observed and reported:

Breakers The collapse of a whole wave when it runs into very shallow water (about half the wave length).

TABLE 2. - SPECIFICATIONS FOR SWELL

LENGTH	Feet	Meters
Short	0 - 300	0 - 100
Average	300 - 600	100 - 200
Long	> 600	> 200
HEIGHT		
Low	0 - 7	0 - 2
Moderate	7 - 13	2 - 4
Heavy	> 13	> 4

Surf The broken water between the shoreline and the outermost line of the breakers.

Breaking sea The partial collapse of the crest of a wave, caused by:

(*a*) action of the wind;

(*b*) steepening of the wave when it meets a contrary current or tidal stream;

(*c*) steepening of the wave when it runs into shoal water not shallow enough to cause a breaker.

2.3.3.2 ICE

Sea ice can be recorded according to the code given in Tables 3 and 4. A revised ice code and classification with illustrations is being prepared by the World Meteorological Organization. The nature, amount and size of the ice should be recorded, using the special observation codes.

2.3.3.3 COLOR

By "color" of the sea is meant the color of the sea water and not that of light reflected from the surface, nor the reflection of the clouds and the sky. The color depends on the scattering of light by water molecules and by sus-

Table 3. - Code for reporting the state of ice

0	Ice-free
1	Loose ice or new ice
2	Fast ice (up to 15 cm)
3	Drift ice (floes up to 15 cm)
4	Pieces of ice pressed together (ice breccia), or tight drift ice (raffed ice)
5	Open water along the coast
6	Strong fast ice (> 15 cm thick)
7	Strong drift ice (> 15 cm thick)
8	Pack ice
9	Ice pressure
10	Unknown

Table 4. - Ice code for shipping
(Baltic Code)

0	Free for all shipping
1	Free for steamers; difficult for sailing ships
2	Difficult for steamers; closed for sailing ships
3	Possible for powerful steamers
4	Possible only for steamers with ice protection
5	Possible with icebreakers
6	Open way in ice exists (made by icebreakers)
7	Shipping temporarily stopped
8	Shipping stopped
9	Shipping possibilities not known, (e.g., because of visibility)
10	No report

Table 5. - Forel water color scale code

Code	Description
00	Deep blue
10	Blue
20	Greenish-blue (or green blue)
30	Bluish-green (or blue green)
40	Green
50	Light green
60	Yellowish-green
70	Yellow green
80	Green yellow
90	Greenish-yellow
99	Yellow

pended matter in the water. The color of clear sea water is nearest to blue. Nature and size of suspended matter then cause variation from this. The greenish color in coastal waters, for example, depends largely on the amount of so-called "yellow substance" present. Color changes indicate different water masses and boundaries between them.

Color is usually estimated according to the Forel (or Osvald) color scales, or described exactly with the simple color adjectives. The Forel color scale is given in Table 5. The chemical methods used for measuring the color of fresh water (e.g., platinum-cobalt or methyl-orange standards) cannot be used in sea water. Several special kinds of optical apparatus can be used, but these require that the determination should be made immediately at the station where water samples are taken. References for these methods are given at the end of this Section.

Visual observations (underway or at the station) are made on the shadow side of the ship, in order to minimize the effect of sun glitter. The estimation of the color (in the Forel scale) at stations should be made against the white (Secchi) disk suspended in the water at a depth of 1 meter (see the de-

termination of transparency with the Secchi disk, Section 2.3.1.5. All discolorations of the water (e.g., phosphorescence) should be recorded, as should observations of drifting detritus and objects on the surface.

2.3.3.4 Tides, surges, water level

Continuous recording of tides is made by special tide gauges. Special observations are made at coastal stations by reading graduated water-level gauges on piers. The reference level of these gauges should be selected according to the standard practice in the country (e.g., mean low water, lowest low water, mean sea level, etc.). Information on tides is usually available in tide tables issued for certain specific areas or ports, and usually computed for a year ahead. The observers should make themselves familiar, from special publications, with the nature of the tides (i.e., diurnal, semidiurnal, range, etc.) in the area of interest.

2.3.4 Explanation of terms

Brackish water. Water with salinity lower than that of normal sea water (usually below $30^{o}/_{oo}$ S).

Chlorinity. Amount of chlorine and other halids in one kilogram of sea water, in grams.

Convergence. The meeting of ocean currents or two air masses.

Detritus. Any loose material; usually the remains of plants and animals after disintegration or wearing away.

Divergence. The opposite to convergence. Moving away from each other.

Drift ice. Numerous small pieces of floating ice of which the total area is less than that of the total water area in which the ice lies.

Extinction coefficient. The rate that light intensity decreases with distance in water.

Halogens. Group of chemical elements, comprising chlorine, bromine, iodine.

Hydrography. The science and practice of surveying oceans and seas. It excludes biological matter.

Hydrostatic pressure. Pressure exercised by the water column.

Messenger. A metal weight which is sent down on cables to manipulate suspended instruments.

Pack ice. Numbers of large pieces of floating ice that have come together and lie more or less in contact.

pH. Hydrogen ion concentration; a measure of the alkaline and/or acid property of the water.

Phosphate. A salt or ester of phosphoric acid, or a negative ion containing phosphorus and oxygen (PO_4). A very important nutrient salt in the sea.

Photocell. A cell or a vacuum tube whose electrical properties are modified by the action of light.

Refractometer. Any of various instruments used for measuring refraction.

SALINITY. The number indicating the amount of salts, in grams, in a kilogram of sea water when all the carbonate has been converted to oxide, the bromine and iodine replaced by chlorine, and all organic matter completely oxidized.

SIGMA-T. Density of water of given salinity and temperature at sea-surface pressure.

SPECIFIC VOLUME. Volume per unit mass *in situ*, reciprocal of density *in situ*.

TYNDALL EFFECT. Back scattering of light from minute particles suspended in the air or water.

TRACE ELEMENT. Elements occurring in natural waters and in organisms in minute quantities.

TURBIDITY. Cloudiness of a solution caused by suspended matter.

YELLOW SUBSTANCE. Brownish-colored organic compounds of unknown composition (related to humic acid) occurring in natural waters and derived from the decomposition of organic matter.

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MANUAL OF METHODS IN FISHERIES BIOLOGY

compiled by

T. LAEVASTU

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Section 3. Observations on plankton, benthos, nekton and sea birds

FOOD AND AGRICULTURE ORGANIZATION OF THE UNITED NATIONS
ROME 1965

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SECTION 3. OBSERVATIONS ON PLANKTON, BENTHOS, NEKTON AND SEA BIRDS

3.0 INTRODUCTION

This Section gives detailed directions on the collection of biological material other than the species of economic importance, which are dealt with in the next Section. It does not deal with the problems of planning field collection work which, in the case of plankton, may be of especial intricacy, but only with the manipulative operations of collection, handling and preservation. However the collection plan is of very considerable importance and should be adhered to as closely as possible. Each expedition plan should contain instructions not only as to places and times of collection, but also as to the modifications of this plan that should be introduced if and when necessary.

Plankton collection methods are of two principal kinds: those that take plankton from samples of water, and those that place collecting equipment in the sea and take samples of plankton from the open sea. The latter then fall into two classes: those that take single samples and those that make a continuous sampling over an extended traverse.

3.1 PLANKTON SAMPLING AND ANALYSES [to follow]

[At the time of going to press most of these methods are under active review by international working groups. The text of this subsection will therefore be issued later as a separate fascicule.]

3.2 OBSERVATIONS ON NEKTON IN GENERAL

In addition to the work on economic species, described in Section 4, other fish in the study area may have to be observed and collected. Collection is usually done with commercial fishing gear. Details of the gear used, location, depth of water and the time of fishing must be recorded. Special collecting gear is sometimes used, such as young fish trawls and large vertical plankton nets, for sampling fish larvae and megaloplankton.

Special experimental gear, which usually is miniature commercial fishing gear, is used from research vessels to catch pelagic animals.

Some nektonic animals which spend part of their life on or close to the bottom (e.g., during daytime) are caught with beam and high-speed dredges.

Observations on the appearance of nekton should be made besides direct collecting; for example, fish shoals, flying fish, mammals, the behavior of the shoal, etc. seen, should be noted in the log.

All observations on pleuston such as on floating logs, floating seaweeds, the discoloration of the sea, etc., should also be carried into the log.

Most of the work on nekton is carried out by methods similar to those used for commercially important species as described in Section 4.

3.3 BENTHOS SAMPLING AND ANALYSES

3.3.1 Sampling of benthos

The qualitative study of benthos is usually conducted with various dredges, such as the regular beam dredge, the scoop, the anchor, and the high-speed dredge for catching fast-moving animals on the bottom, bottom plankton net, etc.

When dredging care should be taken that enough cable is paid out (at least three times the depth of the water) and that the dredging speed is not too high, to ensure that the dredge is towed along the bottom. In shallower water the vibration of the cable will tell whether the dredge is on the bottom or not.

Considerable skill is needed when dredging on rough bottoms and the rigging of gear for rough bottoms differs from that for good bottoms. It is often advisable to arrange a "weak spot" close to the dredge so that if it catches immovably on a rock, the gear is detached and perhaps lost, but no damage is done to the cable or winch.

Attempts have been made to mount counting wheels on the dredges for determination of the length of haul. These counting wheels function satisfactorily only if the dredging speed is slow, the dredge relatively heavy and the bottom consists of consolidated material. In most cases however, dredges jump considerably on the bottom and/or dig occasionally into soft material and incapacitate the counter wheel so that the estimation of the length of haul becomes questionable.

Submarine photography and television have been used on a few occasions for investigations of epifauna. Although these instruments give a picture of the nature of sediment surface and the population of macroepifauna on it, they are not useful for quantitative benthos work for fisheries purposes, because the infauna on the surface layer is usually the most important benthos fish food.

Various grabs are used for quantitative studies of benthos the most common being Petersen and Van Veen grabs, which have a working area of 0.1 or 0.2 m^2. The spring-loaded grab is among the more expensive and complicated devices for this work. The various grabs usually have different working capacities according to the kinds of bottom, and a volume correction can be applied for greater precision.

The bottom sample upon arrival on board is washed through a set of sieves (usually with 2-, 1-, 0.5- and 0.2-cm mesh openings) after a small (about 50 g

wet weight) composite sample of the bottom substrata is taken for sediment study. The animals are carefully collected from the screens and preserved in 60% alcohol or in 4% formaldehyde. The containers are labeled with the following data: date, position (station number), depth of water, the area of grab, the volume of sample, name of the collector, and special information such as the environmental data T.S., the type of sediment etc.

For a preliminary benthos survey on a limited fishing ground, 20 - 70 bottom samples give an approximate picture of the quantitative and qualitative distribution of benthos. It is very helpful, when experimental trawling is carried out in unknown waters, especially in tropical and subtropical areas, if a number of benthos samples are collected at the same time.

3.3.2 Aquatic vegetation analysis

Vegetation beds should be plotted on the map of the lake, using standard symbols for the types of vegetation found. These symbols are:

— for floating vegetation
| for emergent vegetation
— for submergent vegetation

Vegetation stations should be numerous enough to give a good cross section of the plants in the lake or stream. The exact number will have to be determined by the technician making the analysis, according to his best judgment.

In lakes, a vegetation station 10 meters by 10 meters is suggested. In streams, 3-meter strips should be adequate.

For each species of aquatic plants found, enter on the record form the information called for.

Depth range. Give range in depth in which plant is found, i.e., 0.5 to 3 meters.

Relative abundance. Use symbols as follows:

S Sparse, if only scattered plants are found

M Medium, if spaced 0.5 to 3 meters apart

D Dense, if closer together than 0.5 meters, or forming a closed mass

Remarks. Note whether plants are marl covered by placing a C in this column on the record form. Note also flowering, fruiting or budding of plants, using symbols: Fl - flowering; Fr - fruiting; and B - budding or winter buds.

If identification cannot be made in the field, specimens should be preserved for later study. The following procedure for collecting plants is recommended.

1. Select an average plant.

FORM 1. - BOTTOM FOOD ANALYSIS LOG

Lake or Stream ..... Date .....

Depth ..... Area of bottom sampled .....

Type of dredge ..... Type of bottom .....

Vegetation ..... Volume of sample cc

Organisms in sample	Numbers

Determined by: .....

Form 2. - Aquatic vegetation record

Lake or Stream . Date .

Species	Depth range	Relative abundance	Remarks

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Section 4. Research on fish stocks

FOOD AND AGRICULTURE ORGANIZATION OF THE UNITED NATIONS
ROME 1965

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SECTION 4. RESEARCH ON FISH STOCKS

4.0 INTRODUCTION

The whole object of research in fisheries biology is to obtain information on fish stocks, and consequently the focus must be on the work described in this Section. Work on the environment described in Sections 2 and 3, while essential, must be held in balance with that of this Section as described in Section 1.

Much of the work with which this Section deals is of a routine nature, and requires a detailed operational plan. This must be formulated by the research biologist at the commencement of the program. An operational plan for routine operations will take into careful consideration a number of statistical principles covering the choice of samples, the number of samples to be taken at each time and/or place and the size of each sample, as well as giving precise instructions as to techniques.

4.1 COLLECTION AND PRESERVATION OF MATERIAL

4.1.1 Collecting with experimental gear

Special gear is often used to collect samples of fish which are not normally caught with commercial gear, and small-scale commercial gear is used on research vessels in areas and seasons where no or little commercial fishing is done. Various plankton nets are used to catch fish eggs and larvae; and bottom egg nets, specially designed ring trawls and young fish trawls are used, each for its particular purpose. (See Section 3 for collection of plankton, benthos and nekton.)

Night-light fishing is sometimes done to collect positively phototactic fish and fish larvae. The light with a reflector, in a watertight cover, is submerged just below the surface, and a fine-meshed dip-net is swept back and forth through the water under the light.

Poisons are sometimes used to collect fish in shallow water, especially among reefs. The best poison for this purpose is ground cube root, 10 kg of which is sufficient to treat an area of about 10×10 meters if the current is slight and the depth does not exceed 2 meters. The poison should be thoroughly mixed with water in a bucket and then distributed on the surface, in midwater and on the bottom. The work should be done on slack low tide. Certain species will be affected by the poison almost immediately, while others may show no

Form 1. - Fishing log

(*a*) Vessel ..... (*b*) Journal No. ..... (*c*) Date .....

(*d*) Station No. ..... (*e*) Locality (area) .....

(*f*) Lat. ..... (*g*) Long. .....

1. Depth (of water) — 1.1 ..... — 1.2 Nature of bottom .....

2. Sea — 2.1 Weather ..... — 2.2 Wind ..... — 2.3 ..... — 2.4 Color ..... — 2.5 Current ..... — 2.6 Water temperature ..... — 2.7 Depth of thermocline ..... — 2.8 Air temperature ..... — 2.9 Barometer .....

3. Wire out — 3.1 Gear, type ..... — 3.2 ..... — 3.3 Wire angle ..... — 3.4 Speed of vessel ..... — 3.5 Direction of haul .....

4. Time: — 4.1 Gear-setting started ..... — 4.2 Gear out ..... — 4.3 Hauling in started ..... — 4.4 Hauling in finished .....

5. Principal species retained and sizes — 5.1 Depth of capture ..... — 5.2 How fish located ..... — 5.3 Total catch ..... — 5.4 Disregarded ..... — 5.5 ..... — 5.6 Principal species discarded and sizes ..... — 5.7 Samples taken .....

6. Remarks .....

effects for several minutes. A diligent effort should be made to collect all fish killed by the treatment, regardless of size or variety. To find the very small specimens may require a thorough search of the bottom with the use of a face mask. The area searched for poisoned fish should be larger than the poisoned area, especially downstream of the poison.

Explosives are also used on certain occasions to ascertain the presence of fish or to catch and identify species when schools are sighted at the surface or on echo-sounders. The use of explosives for catching fish is forbidden in most countries and a special permission from authorities is necessary. In obtaining this permission the person(s) concerned must demonstrate ability in the use of explosives and knowledge of the risks. Depending on the circumstances, the collected material (fish) may be examined on the spot or samples may be taken for preservation. If any kind of fishing gear is used, the Fishing log must be filled in. For labeling the collections use may be made of the standard form of label described later.

Notes on Form 1. Fishing log

(*e*). Also state the name or general description (e.g. Wadge Bank).

1.2. If fishing for demersal fish state the type of bottom (and/or type of coast).

2.1. State code.

2.2. State direction and force, code.

2.3. State code.

2.4. Give in Forel scale.

2.5. Give direction (and speed if observed).

2.6. Also state the depths if observed at several depths with reversing thermometer.

2.7. As ascertained from BT data.

3.1. State type, dimension and essential mesh sizes, bait if used, etc. For night-light fishing give the depth and strength of light.

3.2/3.3 - 3.4/3.5. Give the amount of wire out, wire angle and speed and direction of vessel when trawling.

4. Give times so that actual hauling time can be computed.

5.2. E.g., echo-sounder, conventional ground, visual observation of schools, experimental run.

5.3. State the number of baskets, etc., and their approximate weights (include discarded).

5.4/5.6. Give all organisms present in the disregarded catch on commercial vessels and estimate their amount.

5.7. Indicate weather measurements made, samples preserved, etc.

6. E.g., damage to gear, behavior of fish, etc.

Form 2. - Gill net record

Location .....

Date ..... Depth of set .....

Time of set ..... Time lifted ..... Hours set .....

Temperature: Air ..... Water ..... Time .....

Weather: Present ..... Preceding .....

Water: Color ..... Turbidity .....

Type of bottom ..... Vegetation .....

Collector ..... Field collecting number .....

Species collected	Aver. length	Size range	Sex condition	Numbers

Form 3. - Seining record

Location

Date Gear used Length Mesh

No. of hauls Type of bottom

Aquatic vegetation - relative abundance

Air temperature Water temperature Time

Turbidity Field collection number

Collector

Species collected	Size range	Sexual condition	Numbers collected

Forms 2 and 3 are designed for recording the experimental catches in fresh water bodies. With some modifications these forms can also be used for marine work.

If the fish are collected by gill net, the mesh of the net should be entered, stating whether bar or stretched measure is used. Example: Gear 25 mm bar.

If the fish are collected by seine, the entry should be: S, then the length of the seine, then the mesh, stating whether bar or stretched measure is used. Example: Gear S-3-5 bar, which indicates the fish were taken in a three-meter long seine of five-millimeter bar measure mesh.

The mesh sizes are important in determining to what extent a given sample is representative of the total population. In reports the type of mesh measurement, bar or stretched, should always be stated.

4.1.2 Collecting from commercial catch

Commercial catches are the main source of material for population studies by way of an interpretation of the relation between catch and the population from which it is drawn. However, the subject of collecting from commercial catches in this sense (chiefly a matter of sampling) will be dealt with in another Manual in this series. Catches may be sorted by fishermen at sea, but nonetheless commercial catches at sea and in the market are a source of material for other parts of the program of fisheries biology. At sea the discarded part of the catch may be of considerable importance. Firstly, this part of the catch may consist of undersized fish, the study of which may furnish important information concerning recruitment and the prerecruit phase of the fishable stocks. Secondly, study of the catch of organisms of no economic importance may be necessary for an understanding of the ecology of the species of economic value.

Collecting from commercial catches, at sea or in the market, is undertaken according to the requirements of the biological inquiries in progress; the material collected will be treated as described in Sections 4.1.3 and 4.1.4. Careful note should always be kept of the date and place of collection and of any information obtained concerning the manner in which the organisms were caught, and the place and time of capture.

4.1.3 Collecting separate organs and tissues

Scales are used to determine age and the back computation of growth. The selection of fish from which to take scales depends on many considerations chiefly determined by the sampling requirements of the population studies. Special instructions should be prepared by the biologists to guide the field worker in this matter.

The areas from which scales generally are taken are shown in Figure 1, but the area varies from one group of species to another. Scales should be

taken from the side of the fish, avoiding the lateral line since this may have a very high percentage of regenerated scales and scales otherwise disturbed. Scales are taken from the anterior third of the body of herrings, above the lateral line or under the dorsal fin, and from flatfish from the eye side and most often from the middle of the body. If possible, the fish should be washed slightly to remove scales of other fishes that may have adhered to the body. From 10 to 25 scales are pulled out with forceps or a pocket knife and placed in small envelopes, each of which is marked with a log number or with data on the fish, such as species, length, weight, sampling place.

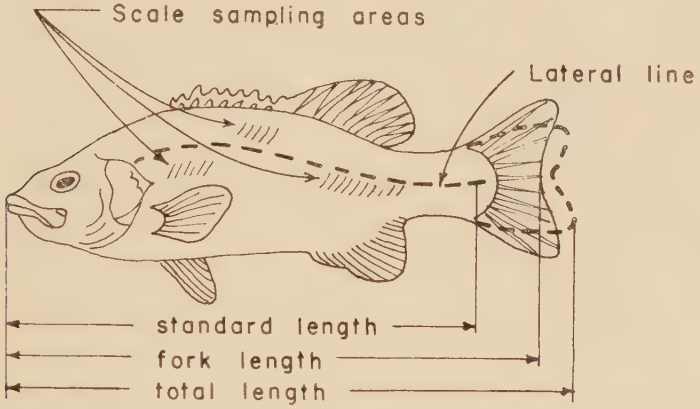


FIGURE 1. - Common fish measurements and areas of scale sampling (from Lagler)

Otoliths are sometimes used for age determination of fish since they also carry regular markings corresponding to events in the life of the fish. They are located in the head of the fish and are part of the auditory apparatus. They are extracted by cutting into the head of the fish and then withdrawing them with forceps. The manner of cutting into the head depends on the type of the fish and is determined only after some amount of experiment (see Figure 2).

Spines and rays also may carry regular markings and thus be useful for age determination. The selection of rays or spines to be removed for this purpose is a matter for determination by the biologists. The rays of the first branched arch are usually selected.

Vertebrae may be collected either for racial investigations or for age determination. In the latter case certain particular vertebrae are generally selected and would be indicated by the biologist. The vertebrae required for such studies should be preserved according to instructions provided by the biologist; in general they are kept in 60% alcohol. In the former case the

entire vertebral column may be required. Counting can sometimes be done at sea, but clear instructions must be given by the biologist, especially with regard to abnormal vertebrae.

Gonads. The examination of gonads to ascertain the state of maturity is usually done in the field. The gonads should also be weighed in fresh condition, because they change considerably when preserved. The counting

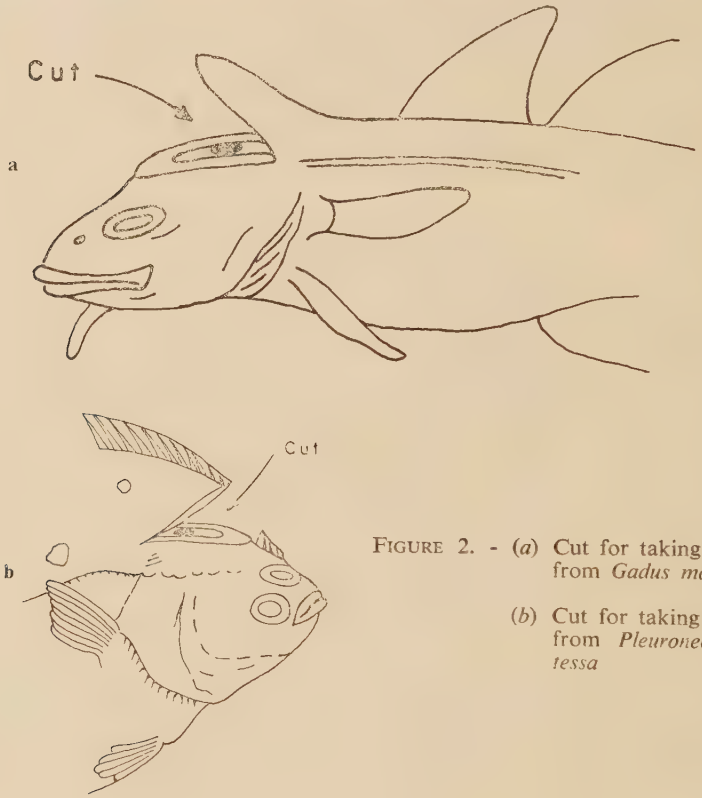


FIGURE 2. - (*a*) Cut for taking otoliths from *Gadus morrhua*

(*b*) Cut for taking otoliths from *Pleuronectes platessa*

of eggs can however be done on preserved material. The gonads are removed by careful opening of the ventral cavity and are preserved in 4% formalin, properly labeled with information concerning the size of fish, its condition, etc.

Stomach. Examination of fish stomachs or preservation of their contents should be done as soon as the fish arrive on board because the enzymes continue to act on food in the stomach after the death of the fish. Stomachs should be collected at random whether empty or full, and should be preserved in 8% formaldehyde in order to stop digestion at once.

Gill-rakers may have to be collected for racial studies. They are obtained by taking the entire branchial arch, and should be preserved in 60% alcohol.

4.1.4 **Preservation of biological specimens**

Whole fish. A 4% solution of formalin is generally used for preservation. This is made by diluting one part of concentrated formalin (37-40%) with 9 parts of water. This must be neutralized with 1 g $CaCO_3$ per liter. The volume of material to be preserved should never exceed that of the preserving liquid. Fish less than 10 cm long should be immersed completely in the formalin. Fish 10-30 cm long should have several narrow cuts made in the abdominal wall a little to one side of the midventral line. Fish longer than 30 cm should be injected with undiluted formalin in several places and the belly should be slit in several places.

All preserved specimens should be properly labeled. The colors of the fresh specimens should be recorded.

Scales are usually kept dry in envelopes. They can also be preserved for shorter times (a week or two) in water in small tubes.

Otoliths are kept dry in envelopes or on special otolith boards. Alcohol (60%) can also be used for preserving otoliths of some species; such storage facilitates the reading of them.

Vertebrae are usually preserved in 60% alcohol.

Gonads are usually not preserved, but if preservation is necessary, it can be done in 4% formalin. However when egg counting is to be undertaken the eggs are best preserved in Gilson's fluid, of which the formula is:

100 ml 60% alcohol

880 ml water

15 ml 80% nitric acid

9 ml glacial acetic acid

Stomach is preserved in 8% formalin.

4.2 FIELD IDENTIFICATION

A field officer should familiarize himself with the main species of fish and other organisms in the area in which he is working and form a general idea of the composition of the fauna of his area. Acquaintance with the main species should be such that there should be no errors in identification of them and that any special forms, in the sense of racial differentiation or malformation from disease or other cause, should be readily noted. As to species of less importance and other elements of the fauna, collections and observations will be made as required by the program. Although this is not the place for an account of taxonomic procedures, or for keys for different groups of organisms, Figure 3 is included for ready reference and shows the principal external features to which reference is made in descriptions of fish. For detailed taxonomic work reference should be made to standard texts.

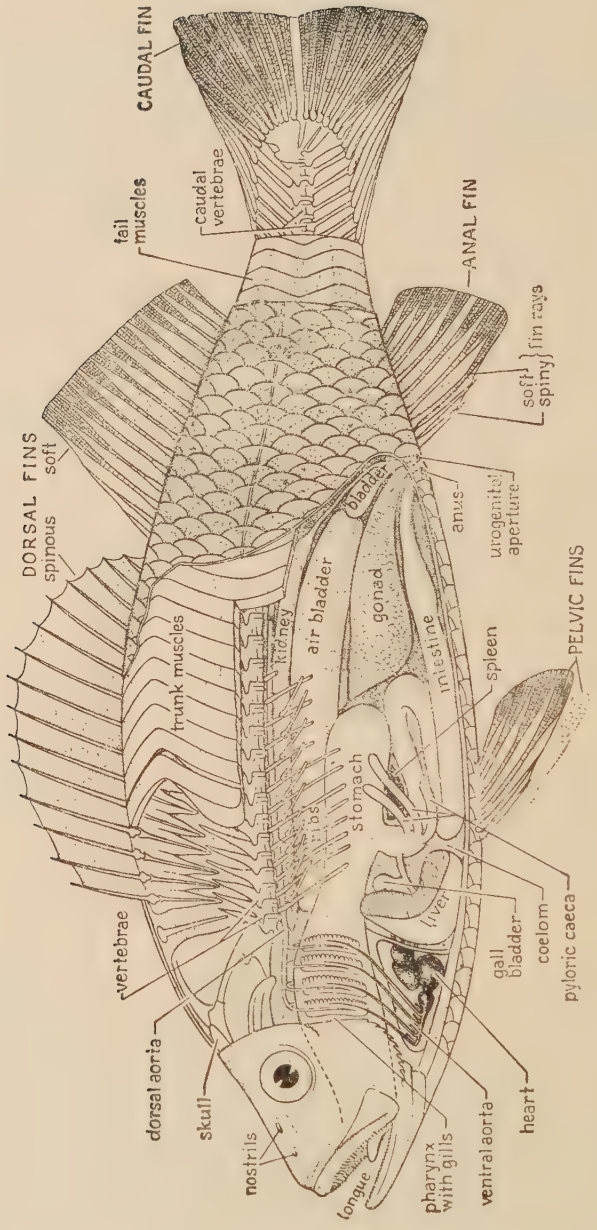


FIGURE 3. - General structure and morphological features of a fish. (T.I. Storer. *General zoology*. New York, McGraw Hill.)

4.3 OBSERVATIONS ON BEHAVIOR AND DISTRIBUTION

Although direct observation of the behavior of fish in its environment has become more practicable, most conclusions on fish behavior are drawn from a variety of observations on the occurrence of fish and prevailing environmental conditions. Certain types of observations should be made systematically in the course of field work, and must be carefully recorded.

(*a*) Schools of fish observed close to the surface must always be recorded, giving the exact position, the estimation of the size of the school, its probable species, the behavior (such as jumping, etc.) and the direction of the movement. Furthermore, the prevailing sea conditions must be recorded simultaneously (state of the sea, color, etc.).

(*b*) The direction of approach of fish to gill nets should be recorded, together with the direction of the layed net and the direction of the currents.

(*c*) The depth occurrence of the fish in gill nets and on trolled longlines should be recorded if possible (e.g., if fish are caught in gill nets mainly on the upper or lower part, etc.).

(*d*) Response of pelagic fish to bait should be recorded.

(*e*) Degree of liveliness of fish caught with trawls and traps should be noted if differing from normal. Also other abnormal conditions of catch could be noted (e.g., abnormally high vomiting, etc.).

Good information can be obtained from echo-sounder (and asdic) observations, and precise correlation of location and behavior with various environmental features can be obtained.

4.4 MEASUREMENTS AND COUNTS ON FISH AND SHELLFISH

Measuring linear dimensions of whole or parts of fish is probably the most widely used technique in fisheries biology studies. Such observations are made with special measuring boards, tapes and calipers. Measurements are usually but not always taken along straight lines. Counts of numbers of fin rays, etc., are less often made in the field and are only briefly mentioned here.

4.4.1 **Length measurements of fish**

The length distributions of fish in samples taken on markets or on research or commercial vessels give the simplest index of the composition of the stock from which the catches are being taken. The choice of which of several possible measures of the over-all length of the fish is to be used for routine purposes depends on many factors, but primarily on the ease and speed with which the measurement can be taken under the given working conditions,

and on the state of the fish (e.g., on whether the caudal fins are usually broken by the time of landing).

It is usually possible to establish a single basic (standardized) length dimension to be used within a particular sampling program. A basic length may even be adopted for use in several programs of research on the same species or group of species of fish (e.g., internationally).

The choice of measurements taken to estimate the size composition of whole catches or landings is considered quite separately from that of the attributes for the purpose of distinguishing species, races, or other subdivisions of stocks. For the former purpose the desirable criteria, apart from unambiguous definition and clear recognition, are:

1. Ease and speed of measurement with simple equipment under field conditions.
2. Existence of a close relation with weight of fish.
3. Repeatability by the same or different observers with high consistency of results.
4. Existing practice, especially with regard to the accumulation of past data.
5. Consistency with measurements which might be made on other fish species at the same time.
6. Consistency with measurements of similar fishes being made elsewhere; probably in that order of importance.

Fulfillment of the third criterion clearly depends on the precision aimed at, and both the first and third are related to the design of the measuring board. The first three criteria are amenable to experimental test.

Some attention has recently been given to studies of personal error and precision in measurement by comparing observations by different observers. If length is normally distibuted there is no bias in the mean, but the variance is increased by observed error; if distributions are rectangular or J shaped (exponential) considerable biases are introduced. However, in comparison with sampling variance, these biases are not usually regarded as being too serious.

Personal errors can, nevertheless, be significant, but they can be minimized by paying attention to the conditions of measuring. Once a basic dimension has been chosen which is not such as will clearly invite errors and inaccuracies in measurement, the instrument to be used can be designed to facilitate that measurement.

Very often, however, differing conditions of sampling and different states of the fish make it undesirable, or even impossible to measure always the same dimension; in such cases a reference length may be chosen to which all other measurements, including the basic length, can be converted if suitable conversion factors have been determined.

The definitions of length dimension given later in this Section apply also to measurements made more for comparative morphometric studies. Such detailed and precise measurements are frequently made in the laboratory rather than in the field.

4.4.1.1 Method of measuring

Over-all length measurements are usually made with the fish lying on its right side, snout to the left, on a measuring board consisting essentially of a wooden or metal base carrying a center scale and having a headpiece (nose block) against which the snout is gently pressed. The mouth is closed, the fish body and tail straightened along the midline and the reading taken from the scale. An attempt is usually made to measure the whole fish in the fresh, wet condition (that is as near to the relaxed live condition as possible); if *rigor mortis* has set in the fish should be gently flexed just before measuring. In certain circumstances (e.g., during tagging experiments) fish may be measured alive; it may then be necessary to take special steps, such as injection of narcotics, to relax the fish during handling.

Rays and other dorso-ventrally flattened fish may be measured while lying straight on their ventral surfaces; the standardized linear dimension of rays is indeed often the disk width rather than over-all length.

Large, fat fish present difficulties. Their lengths may be measured with calipers or from point to point along the body surface with a tape.

Commonly, measuring is done by observers working in pairs, one of whom places the fish on the board and reads the scale, the other records the measurements called out by the first. Various devices have been used to permit measuring by a lone observer. The surface of a part of the measuring board may be divided parallel with the central scale and be of such a texture that erasable marks may be made with a pencil, etc.; or strips of paper may be pinned along the board. In one type of board ruled paper, protected by a covering of tinfoil or of cellophane or similar transparent material, forms the scale, and is pierced with a needle in the appropriate place at each measurement. The board itself may be dispensed with, and a narrow celluloid strip used on any flat surface (e.g., the deck of the ship). It is pierced at each measurement, and the lengths are read against a scale on returning to the laboratory. Devices recently developed use click-counters, arranged in a row along the measuring board, one for each scale interval. From these the length-frequency distribution of a measured sample can be read directly. Use of a simple measuring board, the observations being dictated into a portable tape recorder, has been tried successfully and there have been proposals for various types of automatic or semiautomatic measuring instruments.

4.4.1.2 Measuring damaged fish

Suppose that total length is the basic dimension chosen. If an occasional fish in a sample has its caudal fin damaged, it should not be discarded but its total length should be estimated by comparison with another fish of about the same size, to avoid possible bias arising because damaged fish tend to be larger or smaller than the average.

If whole samples or large proportions of specimens are damaged, another convenient dimension must be measured, for which there is available a con-

version chart based on the calculated regression of total length on that dimension. This may cause a problem in grouping the observations, which is simplified if such measurements are made to millimeter accuracy, converted to total length individually or by millimeter groups, and the calculated total lengths grouped in the normal way. Choice of the other dimension to measure is largely a matter of convenience.

4.4.1.3 Measuring processed fish

Dimensionally the most stable part of specimens of many fish species when they are being dried is probably the head. The head length, however, often varies allometrically with total length and conversion then has to be made by using a chart or table based on the regression of total length (or its logarithm) on head length (or its logarithm).

Conversion keys must be applied only to the stock for which they were determined and should be checked periodically to see whether the regression has changed. If it is found that it does change, it will be necessary to determine the keys anew each season, unless some additional factors are found which permit use of the same key or set of keys. The most likely cause of change in the keys is the probable dependence of the regression used on the growth rate of the fish, it commonly being found that the relative length of the head of a fast growing fish is less than that of a slowly growing fish of the same size. This relation is reflected in the condition factor, and thus usually in the body depth, which tends to be greater in faster growing fish. Body depth and head depth are probably closely related, or at least vary together. This suggests a means of using two measurements such as head depth and head length to estimate total length of dried fish.

In other situations where the recommended standard is not for any reason adopted, conversion tables or charts should be drawn up as described above, from special experimental observations.

A particular question to which careful attention should be paid is the degree of freshness and wetness of the measured specimens. It is common knowledge that fish will shrink rapidly on drying. Normally, when measurements are made on fishing craft or on markets at the time of unloading this problem will not arise, but if samples are taken away for later observation, a means of conversion of measurements to fresh, wet condition may have to be employed.

4.4.1.4 Units of measurement, precision and group size

It has been recommended that the metric system be adopted universally for all scientific measurements relating to the assessment of fish stocks.

The precision with which the results of measurement are stated should be related to, and certainly not higher than, the accuracy with which the meas-

urements are or can in practice be made. This accuracy is not usually more than 99 percent, so that measurements of fish over 10 cm long should not normally be quoted to millimeter precision. The unit interval on the measuring scale is preferably related to the agreed precision of the measurements to be made.

For fish ranging from about 10 to 50 cm in length, quarter- or half-centimeter intervals may be satisfactory.

Choice of the class interval is a matter of judgment. For convenience and brevity it is desirable to make the class interval as large as possible, subject to the condition that it is also desirable to be able to treat all values assigned to any one class, without serious error, as if they were equal to the midvalue of the class interval. These conditions will usually be fulfilled if the interval be so chosen that the total number of classes lies between 15 and 25.

Class limits may be set so that either the limits or the midpoints of the class intervals are convenient round numbers. It is a general principle of measuring that class limits should correspond with a scale mark on the instrument, and the scale numbers corresponding with the marks should be convenient round numbers. Given these criteria, there are two ways of reading the scale.

1. To the nearest scale mark.

2. To the next scale mark above or below.

The first method is usually not good because judgment of which is the nearest mark takes more time than judgment whether a mark is reached or not. It is more subjective and, in the case of fish measuring as opposed to the movement of a needle across a dial, it can be biased by the asymmetry of the display of fish and scale. This can readily be demonstrated experimentally.

If measurements are made to the scale unit above or below with a normal measuring board, the intervals have limits at multiples of whole units and midpoints at half units. If the scale zero is offset by half a scale unit from the headpiece (see Figure 4) the resulting classes have whole-unit midpoints and half-unit limits, and the method is equivalent to unbiased reading to the nearest scale unit with a normal board.

Offset boards have some disadvantages. It may be necessary to group classes in different ways for different purposes, and this cannot conveniently be done if the class midpoints, rather than the limits, are whole-unit multiples. An offset board also cannot be used easily as a scale for other purposes, unless it has a removable headpiece block one half-unit thick. Such an arrangement is undesirable as it unnecessarily complicates the equipment; the removable piece can be mislaid or errors made by the observer not noticing whether it is fitted at the time that measurements are taken.

The differences between measurements to the nearest unit, or to that above or below, may be conveniently shown by considering the limits and midpoints of, say, the 20-cm group (supposed using ½-cm grouping), the 1-mm groups which make up the ½-cm group, and the 1-cm groups obtained by adding two ½-cm groups.

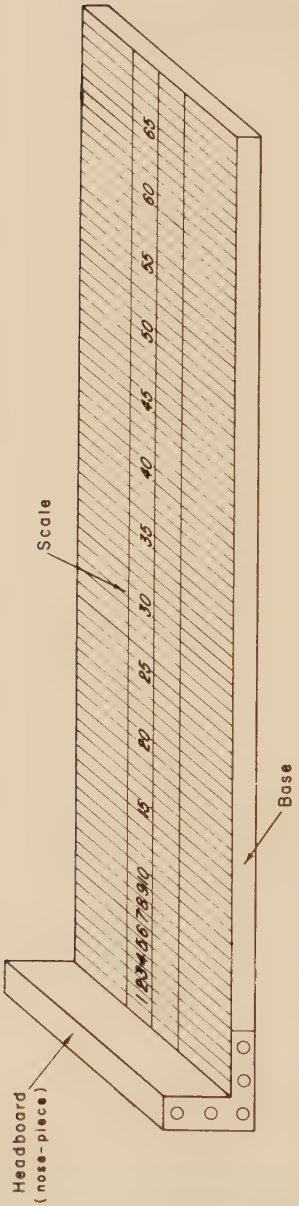


FIGURE 3. - Measuring board

Method of grouping	*Nearest*	*Next above*	*Next below*
Limits of 20-cm group (by ½ cm)	19.75-20.25	19.50-20.00	20.00-20.50
Midpoint of 20-cm group	20.00	19.75	20.25
Constituent 1-mm groups of 20-cm group	198,199,200, 201,202	196,197,198, 199,200	200,201,202, 203,204
Limits of 20-cm group (by 1 cm)	19.5-20.5	19.00-20.00	20.00-21.00
Corresponding ½-cm groups	None	19.5-20	20-20.5

It should be noted firstly that data given to the nearest unit cannot be combined for groups equal to an even number of the original units, e.g., 1 mm to 5 mm is possible, ½ cm to 1 cm is not.

Secondly, combination of data given to the unit below is more obvious to the eye than for data given to the unit above, e.g., classing 201 as 20 is quicker than classing 197 as 20. Again, class intervals are customarily designated by their lower limits; someone aged 35 years 9 months is referred to as 35 rather than as 36. Several arguments thus weigh against measuring to the nearest unit, whether or not this is achieved with the aid of an offset scale.

There is commonly some preference for reading the scale to the unit below rather than to the unit above, but this decision must depend on the design of the measuring board in relation to the dimension chosen for measurement. Thus for fork length, reading errors are minimized if the scale numbers run down the center line of the board. The first number visible beyond the fish is therefore the one read and entered on the recording sheet, and would be the scale mark above. For dorsal extreme length or body length, for both of which the scale numbers would most conveniently lie above the center line, there seems to be no particular advantage in reading to the unit above or below.

We have seen that there are advantages in designating class intervals by their lower rather than by their upper limits. If, as with fork length, there were some small advantages in reading to the scale unit above but designating the interval by the lower limit, then a scale offset by one whole unit can be used to achieve both ends; but for extreme length it is simpler to read a normal scale to the unit below.

4.4.1.5 Design of measuring boards

The special requirements have already been outlined above. Here are given some general principles of design, illustrated with reference to the requirements

for field measurements of total length of clupeoids, carangids and scombroids not exceeding 40 cm. For this purpose a half-meter scale would usually be adequate. The board would, however, probably often be used to measure other kinds of fish, and then an extension piece, or hinged section would permit measurements up to one meter.

If measures of standard (body) length and other dimensions than over-all length are to be measured, it may be necessary to fit a sliding cursor carrying a wire which passes over the fish when it is lying on the board. Such boards also sometimes have a mirror on the base; if the measurement is read with the eye in such a position that the wire and its mirror image coincide, parallax error is avoided. Devices of this kind are more often used in the laboratory for morphometric studies than for routine observations in the field.

The basic data required for the rational design of a scale comprise: (1) the total range of the variable to be indicated, (2) the maximum accuracy and sensitivity required in transfer of information, and (3) the maximum equipment and operational error in terms of bias and variation, the latter in this case being determined by repeated observation of the same fish. When these are known, the scale size, range and number of divisions, can be decided. If there are too few divisions there will be unnecessary loss of information; if too many, time is wasted and a spurious accuracy obtained.

4.4.1.6 Scale divisions

Commonly, for fish of the size range in our example routine measurements are to be made in ½-cm units and special measurements to millimeter units. If the same board is to be used for both kinds of work, and it is convenient if this is possible, then the major scale marks should be a ½ cm apart, with intermediate strokes 1 mm apart. The strokes at whole-centimeter and half-centimeter intervals should be identical, to avoid bias. For the same reason it may be desirable to have a scale number corresponding with each major mark, though this may not be practicable if the numbers are to be engraved the correct size (see below). (Visually, the optimum distance between numbered scale markings is 1 to 2 cm; between unnumbered markings not less than 1 mm.)

Scale numbers and marking strokes should contrast well in tone and color with the scale face. Scale numbers will naturally increase from left to right as the fish is to be measured lying on its right side, and normal visual expectation is that the scale will run in this direction.

There should be some indication, by large numbers or partially thickened lines, of the points which are multiples of 10 cm and perhaps also of the multiples of 5 cm. The scale will then conform with the general principle that all engraved lines and numbers should increase in units, fives or their decimal equivalents.

The ½-cm markings are conveniently continued right across the board which would normally be about 12 cm wide. There should be a median longitudinal line the full length of the board, and the scale numbers should be set

about 2 mm above it, the millimeter marks being on the median line or just above it.

If measurements are to be made to the unit above or below with a normal scale the zero of the scale should be level with the headpiece of the board, which would be about 5 cm high.

The following are the recommended dimensions, in mm, of engraved numbers and scale marks to be read at normal viewing distance of up to 1 m.

Numbers	Minor	Intermediate	Major
Height	2.3	3.1	4.7
Width or stroke thickness	0.4	0.5	0.6
Scale strokes			
Length	2.3	3.9	5.5
Width	0.4	0.5	0.6

With a dark character on a light background a height to stroke thickness ratio of about 6:1 is best; with a light character on dark, a ratio of 10:1 is better. In general the optimum height to width ratio of the character itself is 3:2.

It is sometimes found useful to have a beveled edge to the base of the board, to prevent fish sliding off; under certain conditions, however, this is a hindrance rather than an advantage. The board can usefully have a carrying handle, and if it has attached surfaces in which measurements can be written by a lone observer, it should have a hole or eye for the attachment of a pencil by string, or similar arrangement.

4.4.1.7 Definitions of linear measurements

Over-all lengths may be measured from the snout (U, the position of the maxillary symphysis) or from the tip of the lower jaw (L, the mandibular symphysis). Measurements from L are taken with the mouth closed. If the lower jaw projects much beyond the upper jaw, measurement from S may necessitate provision of a special "stepped" nose piece on the measuring board.

There are three main over-all length measures in common use. These are roughly illustrated in Figure 1. Standard length, the standard dimension of taxonomy, is properly measured from U to the tip of the hypural bone (urostyle). In practice it may be measured to some external feature more or less corresponding with the latter point; this would vary from one species to another but examples are the last scale, or point of silvering, to edge of skin pigment (determined by scraping away the posterior scales), to tip of fleshy peduncle or to the keel. Fork length is measured from U or L to the cartilaginous tip of the shortest, or median, caudal fin ray. It may be difficult

to measure if the tail is split. Total length is measured from U or L, to the tips of longest caudal fin rays, in several possible ways. Measurement may be taken to the tip of the dorsal lobe, of the ventral lobe, or of the longer of the two, or some average of them both (such as to the midpoint of a line joining the two tips or to the point where such a line crosses the median longitudinal axis).

The tail fin may be in the extended position to give normal (total) length or the tips of one or both caudal lobes may be drawn to the longitudinal axis extreme (total) length. Sometimes total length measurements are made with the caudal lobes partially drawn together so that their outer edges are parallel to each other and to the axis. It is therefore clear that precise instructions must be given as to the dimension to be measured and the mode of measuring. In particular, if a normal length is the chosen dimension, it is necessary to standardize the procedure of laying the fish on the board. A common method is to place the head of the fish against the nose piece with the right hand, hold the fish in position with the left hand, and use the right hand to straighten the body of the fish and extend its tail with a single stroking movement.

There follow useful sets of notations and definitions for positions and linear measurement, which are applicable to many types of fish; they are illustrated with reference to a scombroid in Figure 5.

Positions are defined as on the left side of the fish unless stated to the contrary. When side-to-side comparisons are being made, or if necessary for other reasons, distinguish by prefixing " r " or " g " (right or greater) to the notation (or term). This rule may be especially applicable to the dimensions Ph and Vh.

Lower-case letters are used by themselves in the notation where the dimension is not defined with respect to two fixed points, e.g., q, b, g. Otherwise d stands for " diameter, " h for " depth, " and g for " greatest. "

Over-all length measurements are always made between perpendiculars along median longitudinal body axis, from L or U with mouth closed. Measurement is understood to be from L unless otherwise specified, thus e.g., UX Upper (or " maxillary ") dorsal extreme length.

Longitudinal measurements other than over-all length are also often made between perpendiculars, using a measuring board with, for example, a sliding cursor. When they are made radially from point U, using calipers as is recommended, the symbol for the dimension should be in parentheses, and the name followed by the qualifying term " direct. " Point-to-point measurements are sometimes made on big fish, e.g., tunas, by tapes. They would be indicated by the word " surface; " they are not generally recommended. The term " radial " is not recommended to be applied to point-to-point measurements as it invites confusion with fin-ray counts.

All measurements listed from LX to LM and also their " Upper " equivalents are grouped under the general name Total length, LT. LM has also been called " bilobular length " and " total auxiliary length. " It is rather difficult to measure.

The word " extreme " is used in LX, LX' and LX" instead of " maximum " to avoid confusion with the asymptotic size referred to in growth studies. " Great-

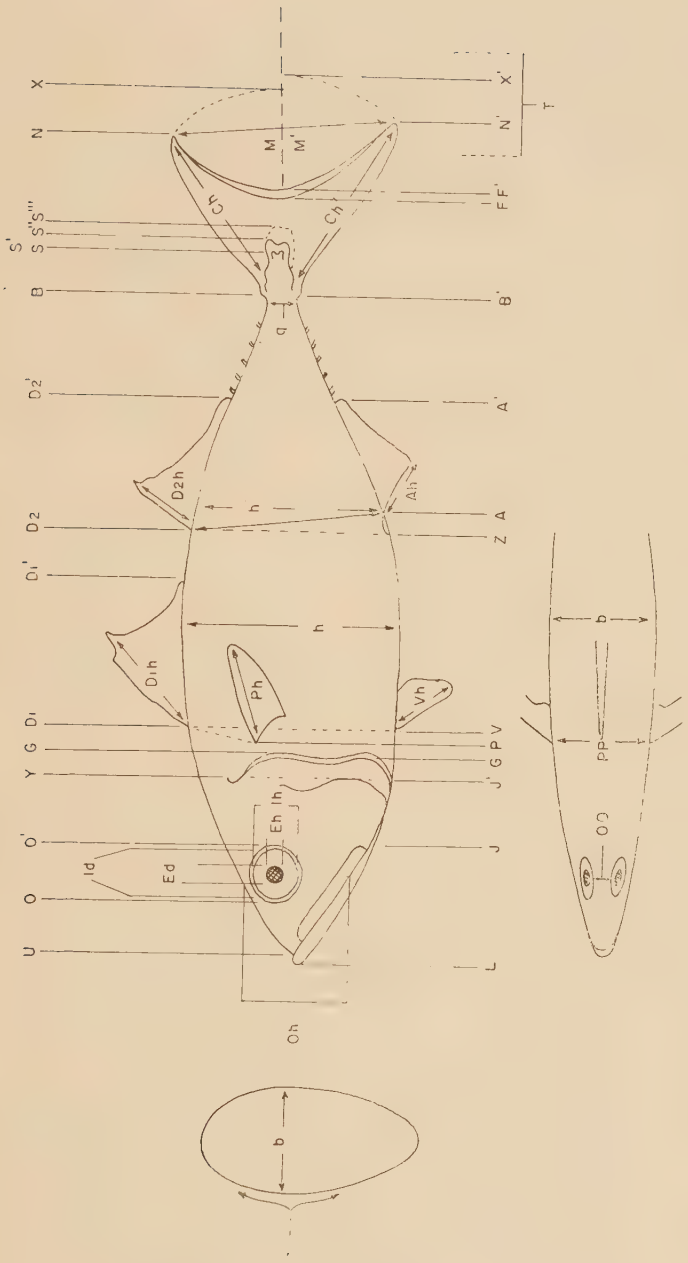


FIGURE 5. - Body measurements of fish
(see text for definitions and nomenclature)

est" is a possible alternative to "extreme" but invites confusion with "greater" for which a suitable alternative cannot be found.

LF and LF' have also been called "median length" or "midcaudal length." The term "standard length" has on occasion been applied to the distance LB as well as to the LS series; this usage is not recommended. It is not known that the ventral body length, LB', has ever been used in practice.

"Depth" is used in terms from Oh to q instead of the alternative "height" to avoid possible confusion with fin heights as measured by length of rays. The ambiguous term "width" is not recommended. Again "width" is not recommended as an alternative to "breadth" in terms for PP and b but "thickness" would be suitable.

Pectoral and ventral fins, Ph and Vh, are usually measured in their folded positions opposed to body size (to keep rays straight) from foremost visible point of insertion to the distal tip of the membranous edge.

In measurements of eyes the limits of Id, Ih and Ig are the boundary of the iris with the black tissue. Ig and Eg are not necessarily equivalent to either Id or Ih, Ed or Eh respectively.

The method of measuring g, in particular the permissible degree of constriction of the belly, remains to be defined precisely. Other girth measurements might be more consistent and perhaps related to conditions relevant to selectivity problems, e.g., if taken level with Y or D1. An appropriate notation could be gY, gD1, etc.

Spread caudal distance NN' has been used for tunas.

In various types of fishes certain of the dimensions listed may be virtually indistinguishable. Thus in the mackerel *Rastrelliger* LM = LM', LS = LS", UJ = UO', UY = UJ', and so on.

Definitions of position

U	Maxillary symphysis
L	Mandibular symphysis
OO	Anterior edge of orbit
O'	Posterior edge of orbit
J	Posterior edge of mandible (buccal commissure)
Y	Gill-cover notch
G	Posterior bony edge of operculum
G'	Posterior membranous edge of gill cover
P	Anterior point of insertion of first pectoral fin ray
D1	Insertion of anterior dorsal (intersection of anterior margin of first dorsal spine, fin held erect, with the contour of the back)
D1'	Position of last ray of anterior dorsal
D2	Insertion of first ray of posterior dorsal
D2'	Position of last ray of posterior dorsal
Z	Anterior edge of cloaca
A	Insertion of first anal fin ray
A'	Position of last anal fin ray

B	Insertion of dorsall obe of caudal fin
S	Posterior tip of urostyle (forward protuberance of hypural blade)
S'	Posterior edge of fleshy peduncle or of pigmented zone
S''	Point of upper caudal keel
S'''	Posterior limit of silvering (either last scale of the lateral line or the posterior limit zone of the scale covered by the peduncle)
F	Cartilaginous tip of shortest (median) caudal ray
F'	Membranous edge of caudal fin at fork
N	Distal tip of the longest dorsal caudal fin ray, lobe normally extended
N'	Distal tip of the longest ventral caudal fin ray, lobe normally extended
M	Point where line NN' intersects median longitudinal axis
M'	Midpoint of line NN'
X	Distal tip of longest dorsal caudal fin ray, with the lobe brought to the median longitudinal axis
X'	Distal tip of longest ventral caudal fin ray, with the lobe brought to the median longitudinal axis

Over-all length measurements

LT and UT	Total length (any extreme or normal length)
LX	Dorsal extreme length
LX'	Ventral extreme length
LX''	Greater extreme length (LX or LX', whichever is greater)
LN	Dorsal normal length
LN'	Ventral normal length
LN''	Greater normal length (LN or LN', whichever is greater)
LM	Median normal length
LM'	Mean normal length
LF	Midcaudal length
LF'	Fork length
LS	Standard length to urostyle (or to some external feature corresponding with it, see commentary)
LS'	Standard length to peduncle (or to pigment under scales)
LS''	Standard length to keel
LS'''	Standard length to silvering
LB	(Dorsal) Body length

Other longitudinal measurements

UJ	Maxillary sheath length
LJ'	Mandibular length
UO	Snout length
UY	Upper head length
LG	Opercular head length
LG'	Gill-cover head length

Lg	Greatest head length
OO'	Orbital diameter
Id	Longitudinal iris diameter (cf. Ih and Ig)
Ed	Longitudinal pupil diameter (cf. Eh and Eg)
O'Y	Postorbital distance
UD1	Preanterior dorsal distance
UP	Prepectoral distance
UV	Preventral distance
UD2	Preposterior dorsal distance
D1D1'	Anterior dorsal fin base length
D2D2'	Posterior dorsal fin base length
UA	Preanal distance
AA'	Anal fin base length

Vertical measurements (perpendicular unless otherwise stated)

Oh	Orbital depth (from orbital crest to lower edge of maxillary, passing over middle of pupil)
Ih	Perpendicular iris diameter
Eh	Perpendicular pupil diameter
YJ'	Head depth
D1P	Back depth (oblique)
D1V	Anterior dorsal depth (or dorsoventral depth)
h	Greatest depth
D2Z	Posterior dorsal depth
D2A	Dorsoanal depth (slightly oblique)
h'	Perpendicular anal depth
q	(Least) peduncle depth

Lateral measurements

PP	Pectoral breadth
b	Greatest breadth
OO	Interorbital distance (at level of pupil centers)

Other measurements

D1h	Anterior dorsal height (distance from insertion to tip of longest spine)
D2h	Posterior dorsal height (distance from insertion to tip of longest spine)
Ph	Pectoral fin length
Vh	Ventral fin length
Ah	Anal fin height
Ch	Dorsal caudal fin length
Ch'	Ventral caudal fin length

Ch''	Greater caudal fin length
Ig	Greatest iris diameter
Eg	Greatest pupil diameter
g	Greatest girth
VV	Length of interventral flap
NN'	Spread caudal distance

Skeletal dimensions

Ax	Axial length (anterior face of vertebra 1 to tip of urostyle)
Sk	Skull length (maxillary symphysis to posterior occipital boundary)
An	Anatomical length (= Ax + Sk)

4.4.2 **Length measurement of mollusks**

1. *Bivalves*

The measurements are shown in Figure 6.

(i) *Length of shell.* The greatest measurement in an anteroposterior direction; this is usually approximately parallel with the axis of the hinge.

(ii) *Width of the shell.* The greatest measurement in a dorsoventral direction; this is usually approximately at right angles to the axis of the hinge and approximately at right angles to the length measurement.

In shells with very irregular shapes such as the oyster, the length is not always greater than the width.

(iii) *Depth of the shell.* The greatest measurement at right angles to the plane of the above two measurements.

Measurements are made with calipers or measuring boards.

Reference: Loosanoff, V.L. and Nomejko, C.A. (1949) Growth of oysters, O. *virginica* during different months. *Biol. Bull. Woods Hole*, 97 (1): 82-94.

2. *Gastropods*

The usual measurement is the length or height of the shell, being the maximum measurement from the tip of the whorl to the tip of the shell. (See Figure 6.)

Reference: Warren, P. J. (1958) A device for rapid single-handed measurement of shellfish. *J. Cons. int. Explor. Mer*, 23 (3): 440-442.

4.4.3 Measurement of crustaceans

Lobsters, crawfish, shrimps, prawns. The length of the carapace is the minimum length by calipers from the inside of the eye socket to the posterior margin of the carapace. In some cases (lobsters) the measurement will be parallel with the midline, in others (some shrimps) it will be from the eye socket to the center of the dorsal margin of the carapace.

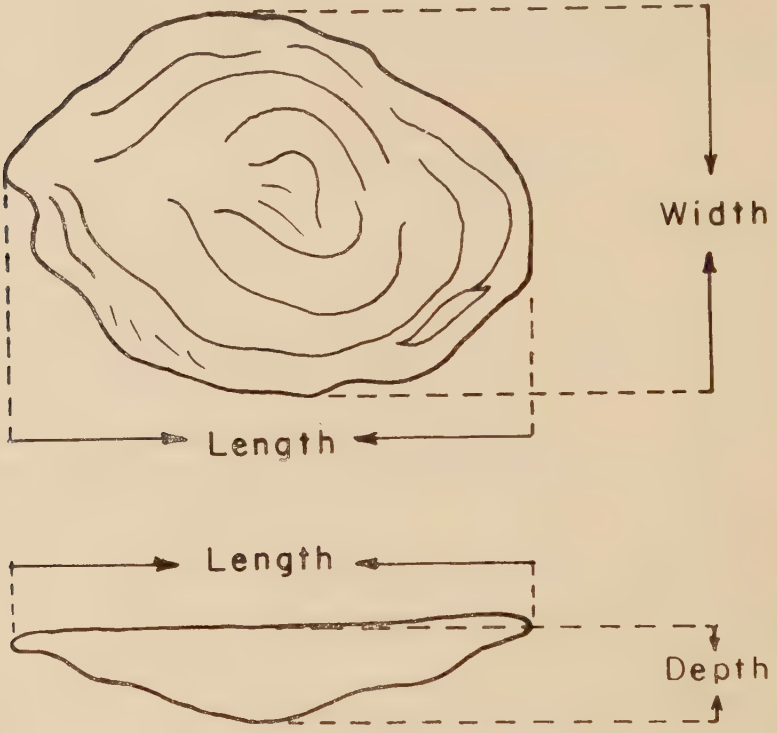


FIGURE 6. - Measurements of shellfish

Crabs. The width of the carapace is the maximum measurement across the carapace, including the spines, if present, at right angles to the median line.

Reference: Cole, H. A. and Mistakidis, M.N. (1953) A device for the quick and accurate measurement of carapace length in prawns and shrimps. *J. Cons. int. Explor. Mer*, 19 (1): 77-79.

FORM 4. - MORPHOMETRY AND LIFE HISTORY DATA SHEET

(*a*) Species..... (*b*) Date..... (*c*) Measured by .

1. Locality						
2. Gear of capture						
3. Weight						
4. Total length						
5. Fork length						
6. Head length						
7. Snout to ins. lst D						
8. Snout to ins. 2nd D						
9. Snout to ins. anal						
10. Snout to ins. ventral						
11. Greatest body depth						
12. Diam. of eye						
13. No. gill rakers						
14. Color						
15. Stomach content — 15.1 Volume						
15. Stomach content — 15.2 Composition						
16. Sex						
17. Degree of maturity						
18. Preserved: Scales						
18. Preserved: Gonads						
18. Preserved: Vertebrae						
18. Preserved: Operculum						
18. Preserved: Entire specimen						
18. Preserved: Other (specify)						

19. Remarks: .....

4.4.4 **Morphological measurements and observations**

The measurements and observations described below are usually made for special studies (e.g., racial studies). The measurements vary from family to family of fish and only a few examples are given. In every case the research biologists must give precise instructions concerning the sampling and the accuracy in the measurements.

Notes on Form 4. Morphometry and life history data sheet

This sheet is generally used for single specimens of large species but can also be used with small modifications for groups of specimens sampled. The sheet presented can be used for measurement of five specimens. The methods of measurement are described in Section 3. The measurements Snout to ins. 1st D *et seq.* are the lengths from the snout to the insertion of the respective fins.

14. Describe the color of fish if necessary (e.g. by exotic species).

15. Give the volume of food in stomach and briefly describe its composition.

17. Maturity scale.

18. Indicate the preservations made and give their serial numbers.

19. Make notes on such factors as depth of water, proximity of land, depth of water where caught, etc.

4.4.4.1 Biometrical measurements on clupeoids

Snout to the insertion of the anal fin.

Snout to the insertion of the ventral fin.

Head length - distance from the tip of the snout to the most posterior point of the margin of the subopercle.

Snout to the insertion of the dorsal fin.

For the measurements of sardines the following dimensions have been defined by Ruivo (1957).

Length to the fork (LF), (Zoological length). Distance from the end of the nose to the end of the middle rays of the caudal fork, the fin being flattened out.

Length of the head (LL'). Distance from the end of the nose to the backward bony edge of the operculum (L').

Predorsal distance (LD). Distance from the end of the nose to the forward origin of the dorsal (intersection point of the forward edge of the first ray of the dorsal, D, with the outline of the back, the fin being flattened out).

Prepectoral distance (LP). Distance from the end of the nose to the anterosuperior origin of the pectoral (intersection point of the forward edge of the first ray of the pectoral, P, with outline of the flank, the fin being slightly lifted up).

Preventral distance (LV). Distance from the end of the nose to the anterior origin of the ventral (intersection point of the forward edge of the first ray of the ventral, V, with the contour of the abdomen, the fin being extended).

Preanal distance (LA). Distance from the end of the nose to the forward origin of the anal (intersection point of the forward edge of the first ray of the anal, A, with the outline of the abdomen, the fin being extended).

Maximum height (H). Vertical distance, at right angles to the axis of the fish, between the dorsal and abdominal outline, being measured at the forward origin of the dorsal.

Maximum thickness (E). Thickness of the body measured between the two points of the flank such as are defined by the intersection of the lateral line with a plan perpendicular to the axis of the fish (transversal plan) and passing by the forward origin of the dorsal.

Length of the dorsal (DD'). Distance from the forward origin of the dorsal (D) to the backward edge (intersection point of the backward edge at the last ray, D', with the outline of the back, the fin being extended).

Length of the anal (AA'). Distance from the forward origin of the anal (A) to its backward edge (intersection point of the backward edge of the last ray, A', with the outline of the abdomen, the fin being extended).

Length of the pectoral (PP'). Distance from the anterosuperior origin of the pectoral (P) to the backward end of the longest ray, the pectoral being extended on the side of the fish in its normal position.

Diameter of the eye (OO'). Vertical diameter of the visible part of the eye, i.e., the distance between the upper edge and the lower edge of the orbit.

4.4.4.2 Biometrical measurements on gadoids

(From LeGall, J. (1952) *J. Cons. int. Explor. Mer*, 18 (2): 236-240.)

Snout to insertion of first dorsal: the distance from the tip of the snout to the base of the first ray of the first dorsal.

Length of the first dorsal: measured from the first ray to the posterior extremity of the first dorsal.

Snout to the end of the first dorsal.

Snout to insertion of dorsal: the distance from the tip of the snout to the base of the first ray of the second dorsal.

Length of the second dorsal: measured from the base of the first ray of the second dorsal to the posterior extremity of the second dorsal.

Snout to the end of the second dorsal.

Snout to insertion of third dorsal: the distance from the tip of the snout to the base of the first ray of the third dorsal.

Length of the third dorsal: as for the length of the second dorsal.

Snout to the end of the third dorsal.

Snout to insertion of ventral: the distance from the tip of the snout to the origin of the ventral.

Snout to insertion of anal: the distance from the tip of the snout to the insertion of the first ray of the anal fin.

Length of the anal: measured from the insertion of the first ray to the posterior extremity of the anal fin.

Snout to the end of the anal fin.

Snout to insertion of pectoral: the distance from the tip of the snout to the origin of the first ray of the pectoral fin.

Length of the pectoral: measured from the origin of the first ray to the posterior extremity of the pectoral fin.

Head length: the distance from the tip of the snout to the posterior extremity of the opercle.

Preorbital distance: the distance from the tip of the snout to the anterior margin of the eye.

Postorbital distance: the distance from the tip of the snout to the posterior margin of the eye.

Diameter of the eye.

Greatest depth: measured from the insertion of the first ray of the first dorsal.

NUMERICAL CHARACTERS (ORIGINAL NOTATION)

N1Dr Number of the first dorsal rays.

N2Dr Number of the second dorsal rays.

N3Dr Number of the third dorsal rays.

NAr Number of the anal rays.

NGR Number of gill rakers: observed on the inferior arm of the first branchial arch (anterior of the left side).

NVe Number of the vertebrae: counted after the first cervical vertebrae immediately after the condylus (not counted) till the last caudal vertebrae (urostyle not included).

4.4.4.3 BIOMETRICAL MEASUREMENTS ON TUNAS

(From Marr, J. and Schaefer, M. (1949) Definitions of body dimensions used in describing tunas. *Fish Bull., U.S.*, 51 (47): 241-244.)

Head length: distance from the tip of the snout to the most posterior point of the margin of the subopercle (depressing the fleshy flap extending posteriorly).

Snout to insertion of first dorsal: distance from the tip of the snout to the intersection of the anterior margin of the first dorsal (erected) with the contour of the back.

Snout to insertion of second dorsal: distance from the tip of the snout to the intersection of the anterior margin of the second dorsal (raised) with the contour of the back, marking the point with a scalpel.

Snout to insertion of anal: distance from the tip of the snout to the insertion of the anal (determined as the second dorsal).

Snout to the insertion of ventral: the distance from the tip of the snout to the intersection of the anterior margin of the ventral, when the fin is extended, with the contour of the body.

Greatest depth: the greatest vertical distance between dorsal and ventral contours.

Length of pectoral: the distance from the insertion of the pectoral to the most posterior point, taken with the fin extended posteriorly and opposed to the side.

Pectoral insertion to insertion of first dorsal: the distance from the insertion of the pectoral fin to the insertion of the first dorsal.

Length of base of first dorsal: the distance from the insertion of the first dorsal to the insertion of the second dorsal.

Length of base of second dorsal: the distance from the insertion of the second dorsal to the intersection of the posterior margin of the second dorsal with the contour of the back.

Spread of caudal: the distance between the dorsoposterior extremity of the caudal and the ventroposterior extremity of the caudal. (When caudal fin is not frayed or shrunken.)

Length of longest dorsal spine.

Length of first dorsal spine.

Length of second dorsal: the distance from the insertion of the second dorsal and with the fin in a normal position. Note that the fin is often extended in a long filament and care should be taken to notice if this extension is frayed.

Length of anal: the distance from the insertion of the anal fin to its distal end. Remarks as before.

Length of longest dorsal finlet: the distance from the insertion of the longest dorsal finlet to the end of its posterior filament.

Diameter of iris: the greatest diameter measured to the margin of the yellow iris and the adjoining black tissue.

Length of maxillary: the distance from the tip of the snout to the posterior end of the maxillary.

Least depth of caudal peduncle: the least vertical distance between the dorsal and ventral contours of the caudal peduncle.

Greatest width of caudal peduncle at keels: the greatest horizontal distance between the lateral contours including the keels (not broken or shrunken).

Number of first dorsal spines: the total number of spines discernible with the first dorsal held erect and with no dissection.

Number of dorsal finlets: the number of finlets following the second dorsal and beginning from the caudal and counting separately the finlets attached to the second dorsal.

Number of anal finlets: counted in the same manner as the dorsal finlets.

Number of gill rakers: the number of anterior rakers on the most anterior gill arch on the left side of the fish. The counts of the rakers on the two arms of the arch are kept separate.

Liver: observations on the liver; markings, shape, weight.

4.4.4.4 Biometrical measurements on sharks

Distance from the tip of the snout to the first branchial fissure.

Snout to insertion of first dorsal.

Snout to insertion of second dorsal.

Snout to insertion of anal.

Snout to insertion of ventrals.

Greatest depth.

Length of pectoral.

Height of the first dorsal: note if there is a spine and its length.

Height of the second dorsal: note as before.

Length of the dorsal lobe of the caudal fin.

Length of the ventral lobe of the caudal fin.

Greatest width of the caudal peduncle at keels.

Number of branchial fissures.

Shape of the snout: design.

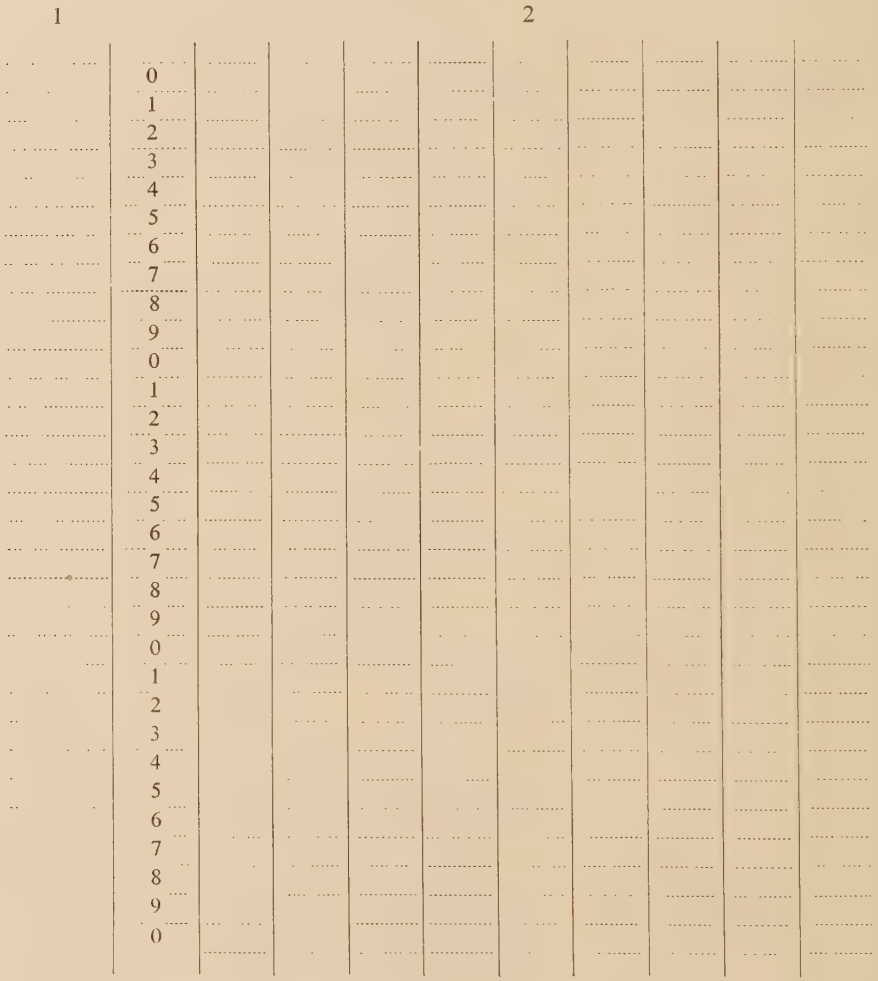
Form 5. - Measurement of fish

(*a*) Species

(*b*) Date (*c*) Locality (*d*) Sheet No.

(*e*) Vessel, Cruise, Station, etc.

(*f*) Gear of capture



3. Remarks

Shape of the teeth: central upper maxillary
lateral upper maxillary
central under maxillary
lateral under maxillary

Distance between the nostrils.

Distance from the tip of the snout and the midst of the line joining the nostrils.

Liver: observations on liver, color and weight.

Denticles of the skin; observed under magnification, and sketched to show their form and disposition.

Notes on Form 5. Measurement of fish

This form is useful for measurement of many specimens of the same species.

(*c*). Give the locality of measurement.

(*e*). Give the name of the vessel and the locality of capture.

1. Use column 1 for lengths. Last digits of the length can be printed and the first digit should be put to suit the length range of fish to be measured.
2. In the columns tick the number of fish in the corresponding length, (e.g. 5 ticks in every column) or use this column for weights if weighing of individual fish is done.
3. Indicate the kind of length measured (e.g. total length, fork length, etc.). Give also remarks on the conditions of measurements and the conditions of fish.

Sometimes filing cards are used for recording fish measurements. One side of the card contains usually the following data: (*a*) species; (*b*) area; (*c*) depth; (*d*) gear; (*e*) vessel; (*f*) locality of landing; (*g*) locality of catch; (*h*) depth of water; (*i*) fishing effort; (*j*) total catch by species, etc.

4.5 WEIGHING

We are concerned here only with weighing individual species for biological purposes, and not at all with weighing catches. The weight of individual fish is required chiefly for the determination of the length-weight relation and condition factors. Weighing of separate organs (e. g., stomach, gonads) is made for various purposes (for determination of the amount of food taken, determination of number of eggs, etc.).

Form 6. - Length-weight data

Lake or Stream ..... Date .....

Method of collection ..... Collector .....

Species .....

Length	Weight	Sex	Length	Weight	Sex	Length	Weight	Sex	Length	Weight	Sex

The only reliable transportable instruments are steelyards and spring balances. Simple transportable laboratory balances are also useful but the weights with which they are used render them slow in use. Shop balances can also be used in fish markets, if a stable base can be provided and care is taken of them in transport. Spring balances are sensitive to temperature changes and many other factors, but small pocket-size spring balances in various ranges (e.g., 0 - 1 kg and 0 - 10 kg), are useful for rough measurements and should be carried on all trips.

The wetness of the fish should be noted for the weighing to have high accuracy. The biologist must decide on the attention to be given to the effect of differences in the amount of stomach contents and the development of gonads. For some work these organs must be weighed separately.

It is often necessary to weigh butchered fish, i.e., fish whose viscera and/or heads have been removed after capture. In most cases it is desirable to convert the weight of butchered fish to the original live weight. Several conversion tables have been established, for this purpose, by bulk of species, differently butchered, and for different sizes of the same species.

4.6 FIELD EXAMINATION OF GONADS AND EGG COUNTS

4.6.1 **Examination of gonads and maturity stages**

The state of maturity of fish can be determined in field examination. This is usually done by exposing the gonads by opening the ventral cavity.

There are several criteria for the determination of maturity stages, which vary from one group of species to another. However, the following classification of maturity stages can be used for most species (Naier, from Bückmann, 1929).

Stage I — *Virgin*: Very small sexual organs close under the vertebral column. Testis and ovary transparent, colorless to gray. Eggs invisible to naked eye.

Stage II — *Maturing virgin* and *recovering spent*: Testis and ovary translucent, gray-red. Length half, or slightly more than half the length of ventral cavity. Single eggs can be seen with magnifying glass.

Stage III — *Developing*: Testis and ovaries opaque, reddish with blood capillaries. Occupy about half of ventral cavity. Eggs visible to the eye as whitish granular.

Stage IV — *Developed*: Testis reddish-white. No milt drops appear under pressure. Ovary orange-reddish. Eggs clearly discernible; opaque. Testis and ovary occupy about two thirds of central cavity.

Stage v — *Gravid*: Sexual organs filling ventral cavity. Testis white, drops of milt fall with pressure. Eggs completely round, some already translucent and ripe.

Stage vi — *Spawning*: Roe and milt run with slight pressure. Most eggs translucent with few opaque eggs left in ovary.

Stage vii — *Spent*: Not yet fully empty. No opaque eggs left in ovary.

Stage viii — *Resting*: Testis and ovary empty, red. A few eggs in the state of reabsorption.

Note: Doubful cases are indicated by referring to two stages, e.g., viii-ii, i-ii, etc. Stages vii and viii are sometimes grouped together as stage vii spent.

The gonads should be weighed in fresh condition, because their weight may change considerably when preserved. The counting of eggs can however be done on preserved material. When counting eggs in the field, measure the total displacement volume of the eggs from the ovary in a graduated cylinder. Remove the eggs from the water and count a portion of them.

Measure the displacement volume of the counted eggs and compute the number as follows:

$$\text{Number of eggs} = \frac{\text{total volume of eggs} \times \text{number of eggs counted}}{\text{volume of the counted eggs}}$$

The diameter of fresh eggs may be measured by placing 10-50 eggs in a row, measuring the total length of the row, and dividing by the number in the row.

4.6.2 **Egg counts**

In life history studies and in fish management, the knowledge of the numbers of eggs produced by each species is essential. The number of eggs must be known if survival is to be estimated and the number produced is significant in fish culture in determining the number of fish required for brood stock.

Egg counts can be made in two ways. First, at the time of spawning when the eggs are fully developed and ready to be laid the females can be captured and, with pressure applied to the abdomen, the eggs can be forced from the body into a pan or jar for preservation and enumeration. If it is not necessary to save the female for some other purpose, the female can be killed and cut open and the eggs remaining after the stripping operation can be added to those stripped from her. If the female cannot be killed, then the number of eggs must be considered to be approximate until such time as it is possible to determine the average quantity of eggs remaining after normal stripping operations.

The second method is to remove the entire ovary from the fish prior to full ripening. The closer to the time of full ripening it is possible to obtain the ovaries, the better it is for counting.

The most accurate enumeration of eggs is the actual count, but this can be very tedious and time-consuming. When actual counts become impractical (as in species with very large numbers of eggs) approximate numbers can be obtained by one of the following methods.

VOLUMETRIC METHOD

Under this method there are two ways to make the egg counts. First, count the eggs in a sample of known volume (v) taken from the unknown lot. Such a sample may be measured by water displacement in a finely graduated cylinder and 10 or 20 cc should be adequate. Then measure the total volume (V) of all eggs in the unknown lot. The total number may then be estimated as follows:

$$X : n = V : v$$

where X is total number in the unknown lot
n is number in sample
V is total volume of all the eggs
v is volume in sample

The second method is to count out 100 eggs and measure the volume by water displacement. If the eggs are small, it may be well to count out 200 or even 300 eggs and obtain the volume. Then the entire sample is measured by displacement, and the total number of eggs would be calculated by the formula given above.

GRAVIMETRIC METHOD

In the gravimetric method there are also two ways of computing the number of eggs. First, weigh a definite portion of the sample, such as 1 or 2 grams, and then count the eggs in the sample. Determine the total weight of the whole lot of eggs and calculate on the basis of the sample count.

The second way is to weigh a known number of eggs, and then the total lot, and calculate the total number.

In the gravimetric system it is important to remove the excess moisture. This may be done by placing the eggs on blotting paper for a given length of time, or by spreading the sample in a large pan and allowing the eggs to be exposed to the air for a definite period of time, or in some cases the samples may be placed in a drying oven for a time.

VON BAYER METHOD

In 1910 von Bayer prepared a table for determining the number of eggs per liquid quart based on the diameter of the eggs. A metal trough of known length, usually 150 mm is used. The groove in the trough is filled with a single

row of eggs, and the number of eggs it takes are counted. The diameter of the eggs is determined by dividing 150 mm by the number of eggs. By referring to his chart the number of eggs per quart is found. These values may be changed into number per cc by dividing the number per quart by 946.4 (the number of cc per quart). By determining the number of cc of eggs in the sample by displacement, and multiplying the number found by the number of eggs per cc, the total number of eggs is found. Von Bayer's chart is reprinted in Lagler's *Freshwater fishery biology*.

PRESERVED OVARIES

When it is necessary to make counts from preserved ovaries, the following method may be used.

Measure the total volume of the ovaries by water displacement. Then obtain volumes of each of three sections, well-spaced, from the ovary. Separate out and count the mature eggs from each ovary section, separating them from the immature eggs and tissues. Take the volume of immature eggs and tissues and subtract from the volume of the sections to get the volume of the mature eggs. Take the average results of three (or sometimes more) counts and compute the number of fully developed eggs per cc and then for the complete ovary.

The count can also be made using the gravimetric method by weighing three samples from various parts of the ovary, counting the eggs as described above, and calculating the total numbers on a basis of weight instead of volume.

4.7 EXAMINATION AND ANALYSES OF STOMACH CONTENT

4.7.1 **Field examination of stomachs**

In a field examination of stomachs the following preliminary notations are used.

(*a*) *Degree of fullness.* Full, half full, nearly empty, empty.

(*b*) *Degree of digestion.* Fresh, half digested, digested.

(*c*) *Type of food in the stomach.* Give the identifiable species or groups of species and estimate their relative abundance (e.g., fish larvae 50%; Euphausids 25%; unidentified 25%).

(*d*) *Stage of the fish* (mainly applicable for Clupeoids).

1° Lean; no traces of fat in the digestive tube.

2° Not very fat; a string of fat not thicker than 1 mm along the digestive tube.

4° Very fat; the digestive tube is completely enveloped by fat.

Exact volumetric measurements of stomach contents and detailed identification of food species found in the stomach are usually carried out in the laboratory.

4.7.2 **Stomach analyses**

4.7.2.1 Processing of stomach content

The processing and analysis of stomach content of marine and freshwater fish are essentially the same. In the following pages are given instructions which apply strictly to fresh-water species and with slight modifications, also to marine species.

CARNIVOROUS OR OMNIVOROUS SPECIES

1. Remove from the formalin jars the number of packets which can be completed in a regular work period and soak in water for 24 hours. This will remove most of the unpleasantness of the formalin. Caution must be used not to leave samples in water longer than 48 hours or they will start deteriorating. A deformalizing solution also can be used very satisfactorily.

2. Place individual digestive tract in a Petri dish or other suitable container and remove all foreign matter (fat, liver, pancreas, etc.).

3. Remove stomach, cut open, flush out organisms with bulb syringe or wash bottle. Some particles may still adhere to stomach walls and these should be picked carefully with forceps. Use as little water as possible in washing out contents.

4. Examine contents under dissecting microscope; separate, identify and enumerate organisms present.

5. Place the individual organisms or groups of organisms on a blotter for not more than one minute to remove excess moisture.

6. After this brief drying, place the various individuals or group of individuals in a centrifuge tube containing 5 cc of water and record volume displacement for each.

7. Compute the percentage of total volume of each organism or group present.

8. If there is a large amount of plankton present, pour sample into centrifuge tube and allow to settle for 15 minutes. Record the volume of plankton. Then dilute to 5 or 10 cc and gently mix concentrate by inverting tube several times. With a 1-cc wide-mouth pipette immediately remove sample before plankters settle, and fill a Sedgwick-Rafter cell as for plankton analysis. Count organisms and multiply by dilution and record total numbers.

9. When the volume of any organism is less than 0.1 cc record as T for trace.

10. Use symbol $<$ 0.1 cc for less than 0.1 cc in grand total.

11. Fish found in stomachs should be identified if possible. Also measure to the nearest millimeter if whole.

12. A record sheet should be made out for each stomach examined, even if empty.

13. Under comments include such information as: kind and number of parasites found, abundance of winter or summer eggs of copepods, etc.

14. Preserve and label any organism not previously found.

15. Stomach contents are identifiable or not. Do not clutter up record form with question marks.

LABORATORY ANALYSIS FOR HERBIVOROUS SPECIES

1. Remove packets as in 1 above.

2. Same as 2 above.

3. Obtain a 2 cc sample from the most anterior part of the intestine. In some cases the entire contents of the whole intestine will be needed and the sample will still not equal 2 cc.

4. Place 2 cc or entire sample if less than 2 cc in a centrifuge tube. Some packing may be necessary to remove air bubbles. A gentle stirring with a teasing needle should be sufficient for the purpose.

5. If a 2 cc sample is obtained, dilute to 10 cc level. Stir and shake to break up any large clumps of some forms. If less than 2 cc is obtained, dilute proportionately. For example, if a 1 cc sample is obtained, dilute to 5 cc; if 1.5 is had, dilute to 7.5 cc, etc. This will give a constant dilution of the concentrate.

FORM 7. - FISH STOMACH RECORD

Species .....
Length ..... Weight ..... Sex ..... Date .....
Determined by .....

Organism	No. of spec.	No. of indiv.	Vol. in cc	% tot. vol.	Organism	No. of spec.	No. of indiv.	Vol. in cc	% tot. vol.
Annelida					Hemiptera				
Mollusca					Coleoptera				
Entomostraca					Lepidoptera				
Malacostraca					Diptera				
Aquatic insects					Hymenoptera				
Ephemeroptera									
Odonata					Total volume				
Plecoptera					Fish				
Hemiptera									
Coleoptera									
Trichoptera					Amphibians				
Diptera					Algae				
Arachnida					Higher plants				
					Debris				
Total volume					Inorganic				
Terrestrial insects					Plant				
Collembola					Animal				
Orthoptera									
Neuroptera					Grand total				
Homoptera									

A - Adult, N - Nymph, P - Pupa, L - Larvae

6. With a 1-cc wide-mouth pipette remove a 1 cc sample and place in a Sedgwick-Rafter cell as for plankton analysis, count organisms and multiply by dilution and record total number on record form.

7. Occasionally large clumps of algae and other vegetable matter will be ingested. Estimate the percentage by volume this material makes up of the total and remove from sample and follow above procedure. This food material which cannot be counted should be considered separately and given only a percentage basis. Other countable items are expressed in percentage by numbers. Thus the sum of the percentage items counted will total 100 percent. For example, a carp sample was made up of 50 percent algal mass and 50 percent countable forms. Of the countable forms, cladocerans made up 90 percent and copepods 10 percent.

8. Stomach contents are either identifiable or not. Do not clutter up record form with question marks.

4.7.2.2 Specification of gut contents

The following outline of methods is based mainly on the review by Hynes, H.B.N. (1950) The food of fresh-water sticklebacks. *J. Anim. Ecol.*, 19 (1) : 35-58. The term *food item* is not intended to refer to a species; it may be a taxonomically heterogeneous group classed together by some other common attribute. It should be borne in mind by interpretation of the results that the method of catch has an influence on the stomach content.

1. *Occurrence method*

   (*a*) The number of fish in which each food item occurs is given as a percentage of the total number of fish examined.

   (*b*) The total number of occurrence of all items is summed, scaled down to give percentage composition of diet. The importance of small numbers and small food items is magnified with this method.

2. *Number method*

   (*a*) The total numbers of individuals of each food item are listed.

   (*b*) Expressed as a percentage of total number of organisms in all fish (not applicable to vegetable food, etc.). Small food items magnified in importance.

3. *Dominance method*

   The number of fish in which each food item occurs as the dominant, expressed as in 1(*a*) and 1(*b*).

4. *Volume and weight methods*

(*a*) The volume or weight of each food item of total food in each fish is given as percentage of weight of fish. The volume of each item may be estimated or measured.

(*b*) As 4 (*a*), but counts of food organisms are multiplied by the known average weights of individuals of each item.
Mean index of feeding = $v.10^5/1^3$ where v = displacement volume of stomach contents and 1 = body length (see Iizuka *et al.*, 1954). This is an accurate method, but occasionally large items cause an incorrect picture of their real importance.

5. *Fullness method*

Estimate the degree of fullness of each gut by a ranking or points system. This is really a form of 4. The accuracy of this method depends on individual experience.

6. *Points method*

Each item in each gut is graded as "common," "frequent," etc., with allowance for the size of the organism as well as its abundance (one large is treated as equivalent to many small). Give rank numbers or points for each category, sum and scale to percentage of total. This is essentially volumetric. It is rapid, easy, and requires no special apparatus; it may be modified by taking fullness also into account, and does not give a spurious impression of accuracy.

4.8 AGE DETERMINATION AND SCALE MEASURING

Age determination is one of the most important analyses of fish and has many uses in fisheries research. There are various methods for age determination. One of the simplest but least accurate is the estimation from the length-frequency distribution. This method is not possible with older fish and often gives misleading values also with younger ones. The other possibility is the use of otoliths, spines, rays, vertebrae and scales, which usually, but not always, have marked annual rings. In most cases when scales cannot be used, otoliths are useful. The sagitta or sacculolith from the sacculus of the inner ear is used. In some cases it is necessary to polish the otolith or to break a bigger one. From spines and rays, thin cross-sections are used as well, as from vertebrae where one of the five first prehaemals is taken.

The scales are usually the most trustworthy for age determination when they can be used. However, there are certain irregularities caused both by "checks" and regeneration. Different species have certain peculiarities in the scales which must be learned from practice.

As dried scales are usually used, they must first be soaked and cleaned of adhering fat and mucus. They can be left to rot a few days in a small volume of water and are then washed in peroxide or in 5% KOH. Temporary or permanent amounts can be made, using euparol, glycerin-gelatine and gum arabic. Several scales of the same fish are mounted on one slide.

By counting the true annual rays, the scales can also be used for back computation of the length of the fish at different ages, because there is usually a good relation between the scale measures and growth of fish. Appropriate graphs should be constructed for every species, as the relations between scale measures and fish growth vary slightly from species to species. The scales are measured either on special projection apparatus using a simple slide projector or by use of a microscope's drawing apparatus.

If the age determination, using scales, bones, etc., is impossible, the size-frequency curves are used for the estimation of probable age.

4.9 OBSERVATIONS ON FISH DISEASES AND MORTALITY: PARASITE EXAMINATION

4.9.1 **Field observations on fish diseases and mortality**

All fish which have symptoms of disease should be preserved for laboratory study. This is especially necessary if abnormal mortality of fish is observed. Before preservation, a field examination and description should be made. This examination should include notation of: (1) Gills; color, whether gill lock and mouth are open, presence of parasites, algal growth or mud on gills, etc.; (2) Color of the fish body, discoloration, etc.; (3) External damage of the body; (4) Discoloration or malformation of liver, stomach, etc.

Only dying or recently dead fish may be preserved for further laboratory study.

When mass mortality of fish is observed, the environment should be described in the fullest possible detail. Note especially the winds and currents at the time of the observation and for the previous days. If proper hydrographic survey work cannot be undertaken, water should be sampled; at each station three 1-liter bottles of water should be taken, one unpreserved and one should be preserved with hydrochloric acid (about 7.5 ml; 12 normal HCl per liter) and the other with formalin to get approximately a 2% solution of formalin. It is advisable, if possible, to take samples at several places and at several depths, especially upcurrent and upwind of the place where the dead fish occur. Plankton samples should also be collected. The samples should be sent to the laboratory for analysis as soon as possible.

4.9.2 **Parasite examination**

The parasite examination is of great importance, especially on fresh-water species. Also on marine species they can serve various purposes, e.g., for identification of stocks, etc.

A parasite examination record sheet should be made out for each important fish species of the water studied. Identification of some of the more common parasites can be made in the field. Specimens of those and of the less common or unusual forms should be preserved for laboratory examination. Kill and fix the specimens in Bouin's solution, then preserve in 70% alcohol. Be sure to label completely.

Fill out the record sheet completely. Fill in every blank either with the kind and number of parasites found, or with NONE if none were found. If the organ or area is not examined draw a line through the blank to so indicate.

Form 8. - Parasite record

Lake or Stream .....

Species ..... Length ..... Weight ..... Sex .....

Skin ..... Pectoral: Fins .....

Pelvic ..... Dorsal ..... Anal ..... Caudal .....

Gills ..... Mouth cavity .....

Orbit ..... Eyeball .....

General musculature .....

Stomach ..... Pyloric caecae .....

Rectum ..... Intestine .....

Peritoneal cavity ..... Liver .....

Gall bladder ..... Kidney .....

Air bladder ..... Testes, Ovaries .....

Pericardial region ..... Stomach surface .....

Intestine surface ..... Fresh or ..... Preserved specimen .....

Examined by ..... How taken? .....

FORM 9. - LABELING OF COLLECTIONS

(1) The labels should be made of suitable material (e.g., linen) so that they can be put into the preservative together with the specimens. The writing on these labels should be done with an indelible pencil. Gummed labels should not be used on the outside of jars. The labels should be tied on. An example of the data needed on a label follows:

Index ..... *Species* .....

Date ..... *Time* .....

Locality .....

Measures

Gear ..... *Depth* .....

Observer, Collector ..... *Vessel and Station No.* .....

Log .....

(2) *Index* Indicate with proper codes whether it is plankton, fish stomach, etc.

(3) *Measures* e.g., displacement volume of plankton, total length of fish, etc.; always indicate what has been measured.

(4) *Gear* The gear or method of capture.

(5) *Log* Indicate in which logs the notes on preservation are made.

4.10 TAGGING OF FISH

The purpose of tagging operations is to obtain information on

1. Migrations
2. Fishing mortality
3. Growth.

The planning of these operations involves decisions on the size range of the fish to be tagged, places and times of tagging, numbers of fish to be tagged at each tagging occasion and in the entire program, and methods to be adopted to obtain delivery of recovered tags and tagged fish. These decisions are made

in the light of what is already known of the biology of the species under investigation, and with reference to the problems to be studied and to technical aspects of the operations. At the planning stage consideration must be given also to the following factors which affect the results of tagging experiments.

1. Method of capture and handling of fish prior to tagging.

2. Handling of fish during tagging and its effects on tagging mortality.

3. Tag characteristics in respect of the characteristics and behavior of given species and in respect of recovery of tags.

4. Methods of recapture in respect of types of fishing gear, tags and location of fishing areas, and possibilities of complete reporting of necessary data by fishermen upon recovery of tagged fish.

The technical questions concern the choice of tag, the methods of capturing, handling and releasing the fish. The whole subject will be dealt with in detail in a special manual. Reference is made to an excellent summary on the subject by Rounsefell and Kask (1945).

4.11 INVESTIGATIONS ON FISH EGGS AND LARVAE

Fish eggs and larvae are collected together with the plankton by the methods described in Section 3.

Buoyant eggs of coastal spawning fish are often washed ashore and can be collected on tide marks or in wave wash. Eggs on the bottom are gathered with bottom egg nets which are equipped with a scraper which scratches the eggs loose and leads them into the bag; or a special highspeed trawl is used, which also catches small vagile benthos organisms, such as Harpacticoids, etc.

One of the special applied investigations of plankton samples is that of the identification and enumeration of fish eggs and larvae. Usually, the plankton samples for this purpose are collected with so-called "egg nets" and the collection must be quantitative in order to be able to compute the amount of fish eggs released at a given time and area, which often gives a good measure of the size of the spawning stock of a particular species. In some cases in the early stage of fisheries investigations in certain areas the egg counts are used for determination of the spawning areas and times of certain fish species.

For the identification of the eggs and larvae a special synopsis will be prepared by Fisheries Biology Branch. Laboratories have to collect the descriptions of the eggs and the developmental stage of the larvae of their interest and make type collections of them if necessary. It is often advisable to pick out the fish eggs and larvae before preserving the plankton catch and to let the eggs develop in small volumes of water of the same origin and tempera-

ture. In this way, identification can be established with greater accuracy. The eggs are sorted out in large Petri dishes (diameter 30 cm). It should be borne in mind that during preservation, the pigment often changes.

For the identification of the eggs various criteria should be used, e.g., diameter of the eggs and pigmentation, the shape of germinative disks, etc. During the counting, the eggs are usually classified into the following five developmental stages.

1. U Undeveloped
2. G Germinative disk
3. yE Young embryo
4. pE Embryo with distinct pigment
5. pO Embryo with pigmented eye

4.12 EXPLANATION OF TERMS

ALLOMETRY. Change of size (measures).

CALIPER. A graduated rod or rule with one fixed and one sliding jaw.

CARAPACE. A bony or horny case or shield covering the back or part of the back of certain animals.

CAUDAL FIN. Tail fin.

CONDYLUS. Knuckle, joint.

CUBE ROOT. Root of a tropical American plant furnishing rotenone.

DENTICLE. A small tooth.

DEPTH OF THERMOCLINE. Depth from surface to the upper boundary of sudden temperature change with depth (depth of the mixed surface layer).

DORSAL. Pertaining to, or situated near or on the back.

FACE MASK. Mask used in diving in shallow water.

IRIS. The opaque contractile diaphrahm perforated by the pupil and forming the colored portion of the eye.

LATERAL. Of or pertaining to the side.

MAXILLARY. Of, pertaining to, or designating a jaw.

OTOLITH. Ear stone, a calcareous concretion in the internal ear.

PECTORAL. Of, pertaining to, situated or occurring in or on the breast or chest.

PEDUNCLE. A stem or stalk.

PHOTOTAXIS. A taxis (movement) in which light is the directive factor.

REGENERATED SCALE. Scales of fish where the rings have disappeared in part (being absorbed and/or dissolved).

ROSTRUM. A part suggesting an animal's beak.

VAGILE. Mobile (animals with ability to move).

VARIANCE. Degree of variation, deviation.

VENTRAL. Designating, pertaining to or situated on the belly (or lower surface of the body).

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MANUAL OF METHODS IN FISHERIES BIOLOGY

compiled by

T. LAEVASTU

Fascicule 10

Section 5. Field observations on fishing operations

FOOD AND AGRICULTURE ORGANIZATION OF THE UNITED NATIONS
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SECTION 5. FIELD OBSERVATIONS ON FISHING OPERATIONS

5.0 INTRODUCTION

While a very large part of the data on which fishery biologists work consists of statistics of catch and of effort expended in taking it, the biologist's interest in fishing operations does not cease with the examination of such statistics. In the first place a fishery biologist must, with his technologist and economist colleagues, examine evidence on the nature of fishing effort, especially with regard to such characteristics as selectivity and efficiency. In the second place much can be learned about the behavior of fish from the direct study of relations between the fish and the fishing gear. Fishing gear and the methods of their use have been devised, especially in traditional fisheries, from considerable careful observation of fish behavior, and hence a report of an observation of a particular type of gear in use can of itself be exceedingly informative with regard to resources in the area of observation. In the third place a biologist may gather much information concerning the stocks he is studying by gathering together the observations of fishermen. For these and other reasons we include here some guides on the field work that may be done to gather such information.

5.1 IDENTIFICATION OF FISHING OPERATIONS, METHODS AND GEAR

A principal requirement of reports of observations on fishing is that there should be correct identification and description of the gear seen, and the methods by which they are used.

Fishing operations. This term signifies all operations in moving to and from fishing grounds, fish-searching and actual fishing. In reporting on operations in a particular locality a full account should be given of each phase of these operations, as follows.

1. Movement to and from fishing grounds: distance traveled, time of travel, whether trip is made by fishing vessel unaided or with mother-ship; nature of navigational method.
2. Fish-searching: whether aided by instruments and if so of what type; the signs looked for, such as water depth, type of bottom, current or other features of the sea, birds.
3. Fishing method: identify the method and describe any unfamiliar features of it. Methods fall into five principal classes:

(*a*) *Collect*: picking up mollusks, sponges, etc. and dredging.

(*b*) *Kill and retain, simultaneously*: with weapons and hunting animals.

(*c*) *Kill and then collect*: using poisons, explosives, and electricity.

(*d*) *Attract, then kill and hold*: with baits and hook and line, and some set gear.

(*e*) *Capture, then kill*: with traps and nets.

4. Gear: the following classification, with the diagrams, will assist in identification of gear.

This classification signifies primarily the manner in which the gear itself operates against the fish, as operated or directed by the fishermen. The five main headings show the principal divisions in this sense of operational character whilst the various levels of subdivision indicate structural and operational features that serve this relation between fish and gear.

1. Gear for simple collection
   - 1.1 Baskets and other simple containers
   - 1.2 Dredges
   - 1.3 Dip nets

2. Gear used for simultaneous killing and retention
   - 2.1 Weapons thrust, thrown or projected with retention by hand or line
     - 2.11 Hand instruments
       - 2.111 Lances
       - 2.112 Spears
       - 2.113 Clamps
     - 2.12 Bow and arrow
     - 2.13 Harpoons
       - 2.131 Hand harpoons
       - 2.132 Rifle harpoons
       - 2.133 Gun harpoons
     - 2.14 Rip hooks (snag hooks)
     - 2.15 Gaffs
   - 2.2 Hunting animals
     - 2.21 Cormorants
     - 2.22 Sucker fish
     - 2.23 Otters
     - 2.24 Dogs

3. Gear (and material) used in killing fish which are afterward collected
   - 3.1 Striking weapons
   - 3.2 Poisons
     - 3.21 Released in water
     - 3.22 Blow pipes
   - 3.3 Electrical apparatus
   - 3.4 Explosives

3.41 Thrown explosives
3.42 Rifles
3.5 Weapons thrust, thrown or projected without retention (divide as for 2.1)

4. Gear used in killing and holding fish that have been attracted

4.1 Lines and hooks
4.11 Without hooks
4.12 With hooks
4.121 Gorge
4.122 Curved hooks
4.1221 Watched
4.12211 Hand angling
4.122111 Handline
4.122112 Rod
4.122113 Troll line
4.1222 Unwatched
4.12221 Floated line, drift longline
4.12222 Anchored
4.122221 Standing line
4.122222 Longline, set longline

5. Gear used to capture fish which are then killed and retained

5.1 Stationary gear (with no horizontal movement, fish being brought to the gear by their own movement in response to natural forces, e.g., currents, or to attraction, e.g., light, or reaction to some driving influence, e.g., sound)
5.11 Passive stationary gear
5.111 Traps
5.1111 Barriers
5.11111 Fish hedges
5.11112 Box traps
5.1112 Fish corral, fish weir
5.1113 True traps
5.11131 Gravity traps
5.11132 Snares
5.111321 Wire snares
5.111322 Rope snares
5.111323 Stock snares
5.11133 Whippy bough trap
5.11134 Torsion shutter trap
5.1114 Baskets
5.11141 Ground baskets
5.111411 Fish pots
5.111412 Wire baskets
5.111413 Fyke net
5.1114131 Braced bag
5.1114132 Fyke net with rings

5.111414 Creels
5.111415 Trap net, pound traps
5.1114151 Trap nets with rings
5.1114152 Box nets
5.11141521 Stake nets
5.11141522 Fixed nets
5.11142 Buoyed trap
5.1115 Aerial traps, jumping fish traps
5.11151 Verandah net
5.11152 Raft trap
5.11153 Boat trap
5.11154 Box trap
5.112 Gill nets and tangle nets
5.1121 Trammel nets
5.1122 Gill nets
5.11221 Set gill nets
5.11222 Floating gill nets
5.11223 Drift nets
5.1123 Tangle nets
5.113 Active stationary gear, with vertical movement for capture
5.1131 Lift nets
5.11311 Hand lift nets
5.11312 Stationed lift nets
5.11313 Boat lift nets
5.11314 Water wheels
5.2 Moving gear, with horizontal action
5.21 Bag nets with fixed mouth
5.211 Scoop, dip net
5.2111 Skimming net
5.2112 Push net
5.2113 Dragged bag nets with fixed mouth
5.212 Gape nets
5.2121 Swing nets (stow nets) on stakes
5.2122 Swing nets (stow nets) on anchors
5.2123 Otter-board stow net
5.22 Dragged gear
5.221 Sweep nets
5.2211 Single-walled
5.2212 Triple-walled
5.222 Trawl
5.2221 Bottom trawl
5.22211 Beam trawl
5.22212 Otter trawl
5.22213 Pareja
5.2222 Floating trawl
5.22221 Surface floating trawl
5.22222 Midwater floating trawl

5.23 Seines
- 5.231 Without bag
- 5.232 With bag
  - 5.2321 Beach seine
  - 5.2322 Boat seine

5.24 Surrounding nets
- 5.241 Barrier nets
- 5.242 Spiral nets
- 5.243 Ring nets, purse seine

5.25 Falling nets
- 5.251 Lantern nets cover pots
- 5.252 Cast nets
  - 5.2521 Hand cast nets
  - 5.2522 Cast nets from gallows or sheerlegs
  - 5.2523 Cast nets from boats

5.2 COLLECTION OF INFORMATION ON FISHING OPERATIONS

Fishermen are a source of circumstantial information that can prove of great value in some stages of research programs. Principally this information relates to the location and magnitude of resources, but often extends to behavior. Form 1 illustrates the kind of questionnaire that can be used as a checklist of questions which may be addressed to fishermen and, with its notes, indicates the manner of recording the replies given. Care must be taken, in framing questions, to avoid "leading" the person being questioned into giving an answer which he thinks the inquirer wants to hear or which he believes will serve the fishermen's own purposes.

Questionnaires of the kind illustrated in Form 1 should be used for unit fisheries and with regard to matters of which an informant can claim personal experience. Unit fisheries are usually designated by a name signifying the fishing grounds, or the species caught or the type of gear used, or the type of craft from which the fishing is conducted; sometimes a combination of these features is used. The main divisions for fishing grounds are as follows:

Inland

Cultivated stocks in ponds, etc.
Wild stocks in rivers, lakes, reservoirs, etc.
Estuarine fisheries

Marine

Onshore (beach fisheries, etc.)
Near-shore or neritic
Offshore
- Pelagic
- Midwater
- Demersal

Form 1. - Questionnaire for interviewing fishermen

1. THE INTERVIEW

1.1 Interviewer's name .....
1.2 Date of interview .....
1.3 Plans .....

2. INFORMANT

2.1 Informant's name .....
2.2 Address .....
2.3 Occupation ..... skipper
master fisherman
member of crew
other
2.4 Type of fishing in which informant engages .....
2.5 Fishing unit in which informant works .....

3. THE UNIT FISHERY ON WHICH INFORMANT FURNISHES INFORMATION

3.1 Name of fishery .....
3.2 Fishing grounds .....
3.21 Location .....
3.22 Distance from port or landing place .....
3.23 Nature of grounds .....
3.24 Sea conditions usually encountered on grounds at fishing time .....

3.3 Fishing operations

3.31 Season .....
3.32 Operating program .....
3.33 Amount of time sailing to grounds .....
3.34 Fish-searching methods .....
3.35 Fishing method .....
3.36 Fishing gear .....
3.37 Inboard handling of fish .....

3.4 The fish and the catch

3.41 Usual composition of catch .....
3.42 Seasonal variations in composition and size of catch .....
3.43 Behavior of the fish (migrations and schooling) .....
3.44 Spawning (season, place) .....
3.45 Feeding .....

4. GENERAL OBSERVATIONS

Notes on Form 1. Questionnaire for interviewing fishermen

Use one form for each unit fishery on which informant will give information; that is, when an informant can give information on two or more unit fisheries, use two or more forms.

2.4 Give the name of the type of fishing operations in which informant says he is engaged; if he is engaged seasonally in different fisheries, give both and if possible the proportions of time spent in each.

2.5 Give name of boat or other identification.

3.23 This applies primarily to bottom or foreshore; muddy, sandy, rocky, etc.

3.32 Give average duration of trips; times of departure; turn-around time.

3.34 If aids to fish detection are used report them: note also signs (birds, water color, etc.) looked for.

3.37 Report whether the fish are treated (gutted, etc.) on board and how they are stored.

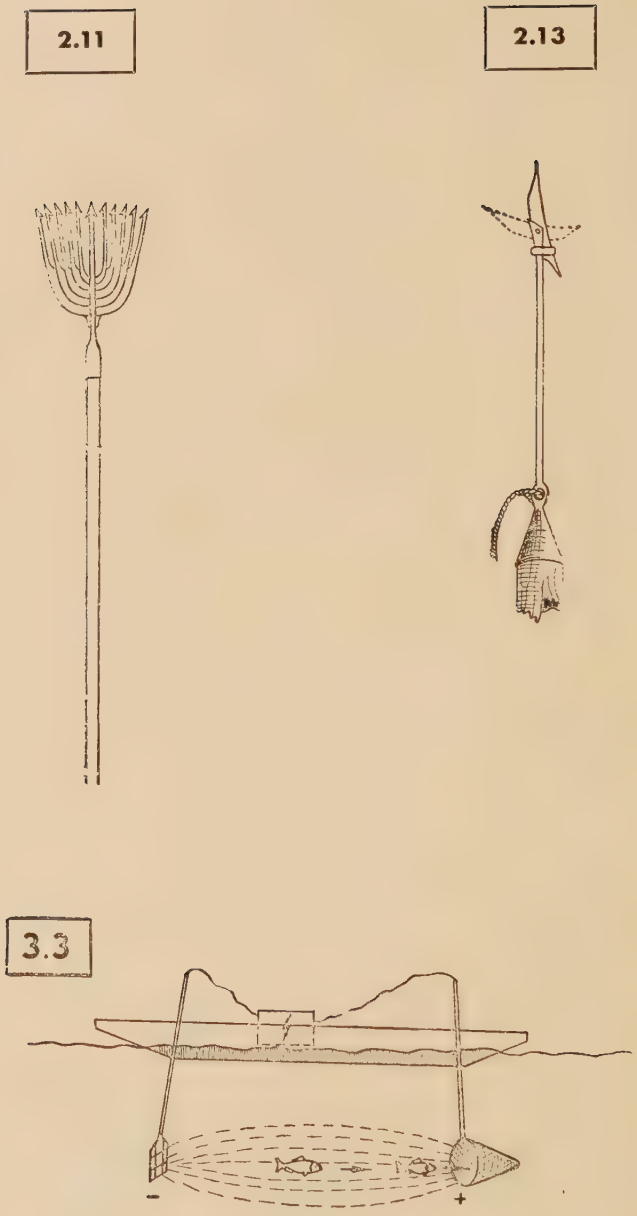

FIGURE 1. - Types of fishing gear
(for explanation see classification)

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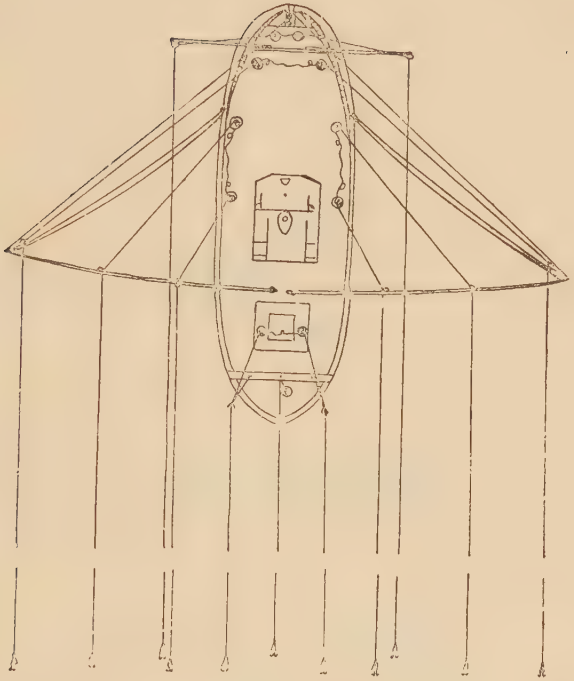

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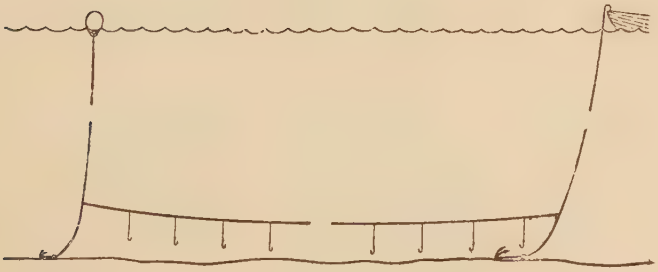

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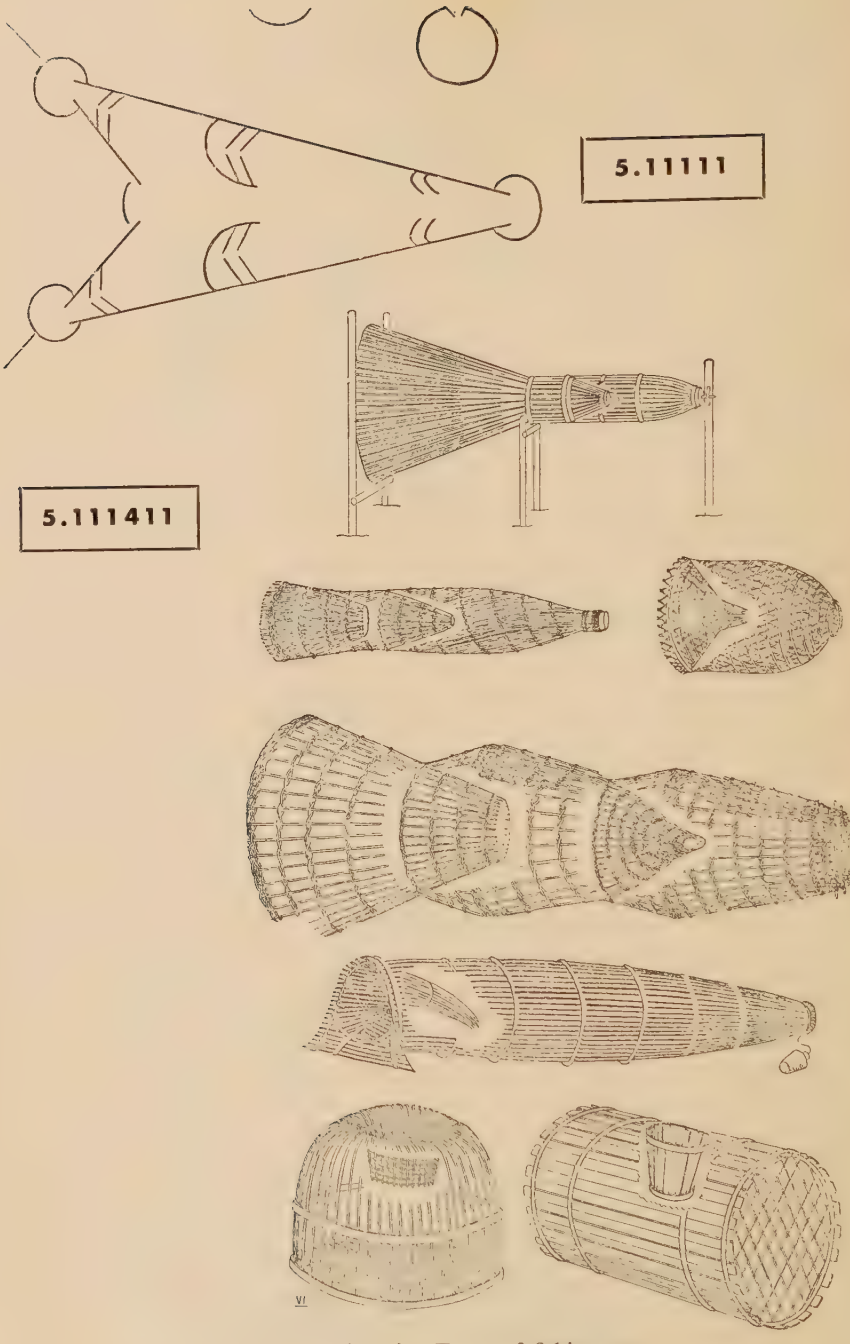

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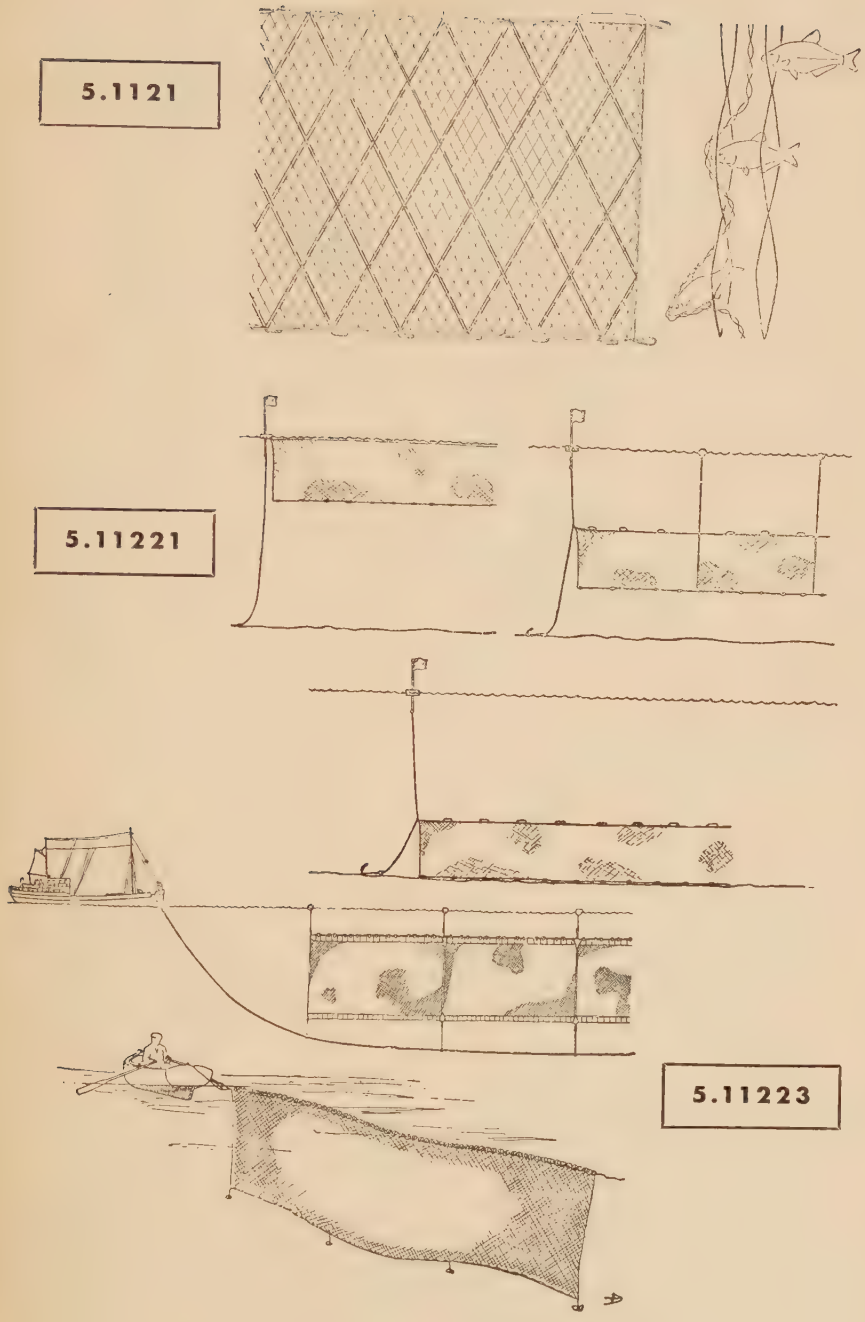

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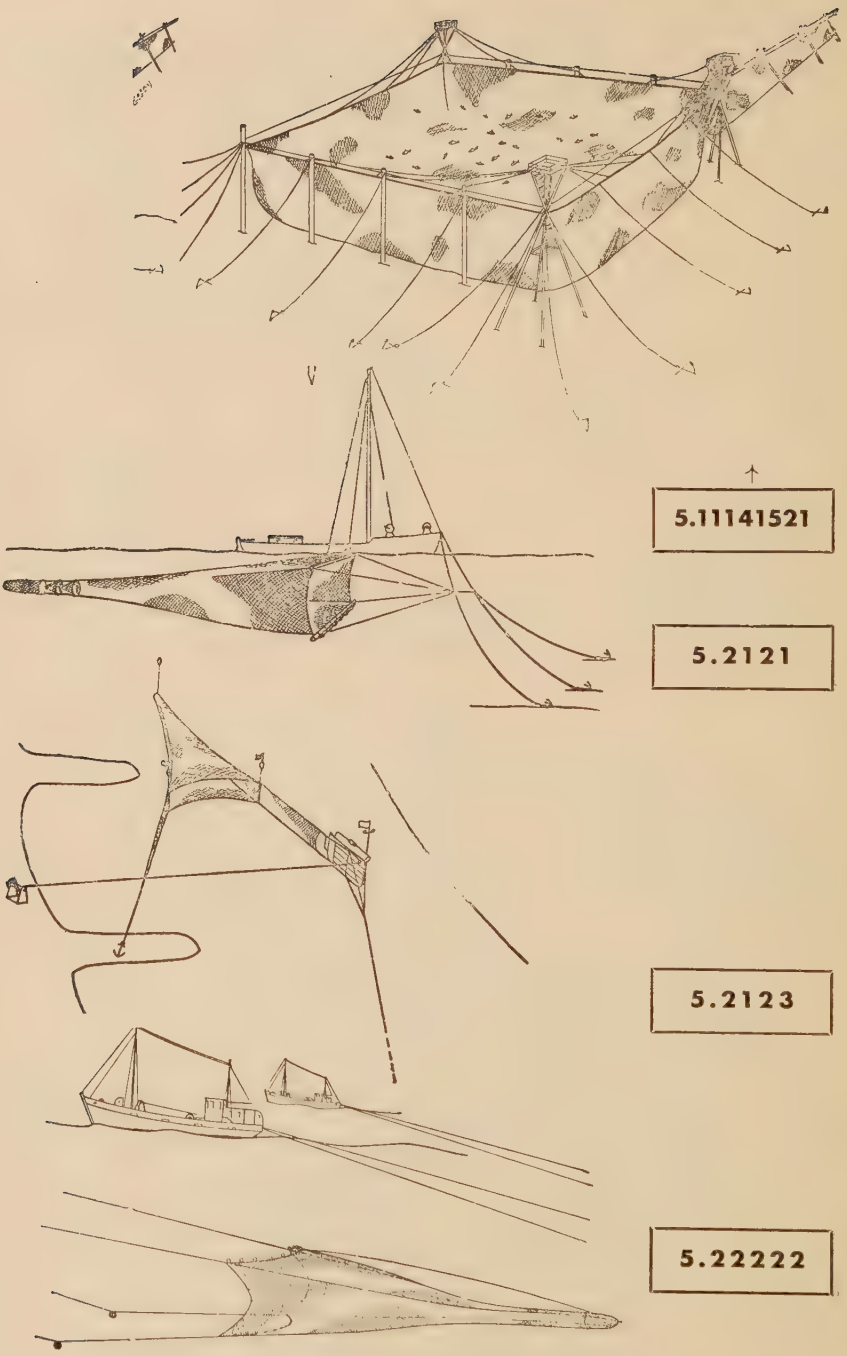

FIGURE 1 (cont.) - Types of fishing gear

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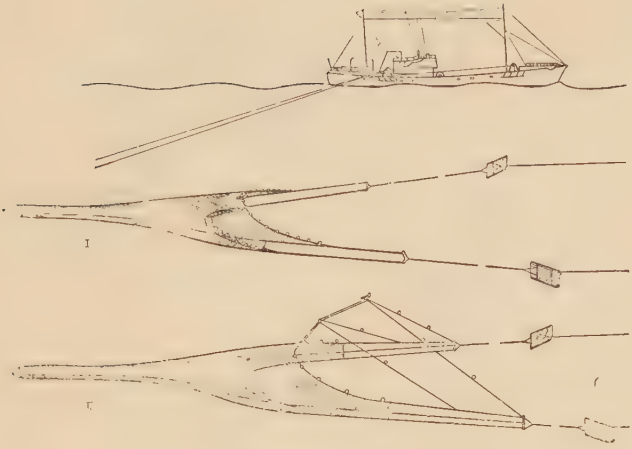

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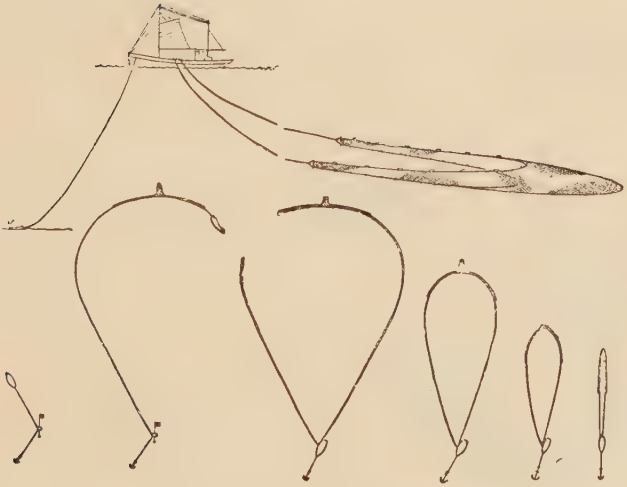

FIGURE 1 (cont.) - Types of fishing gear

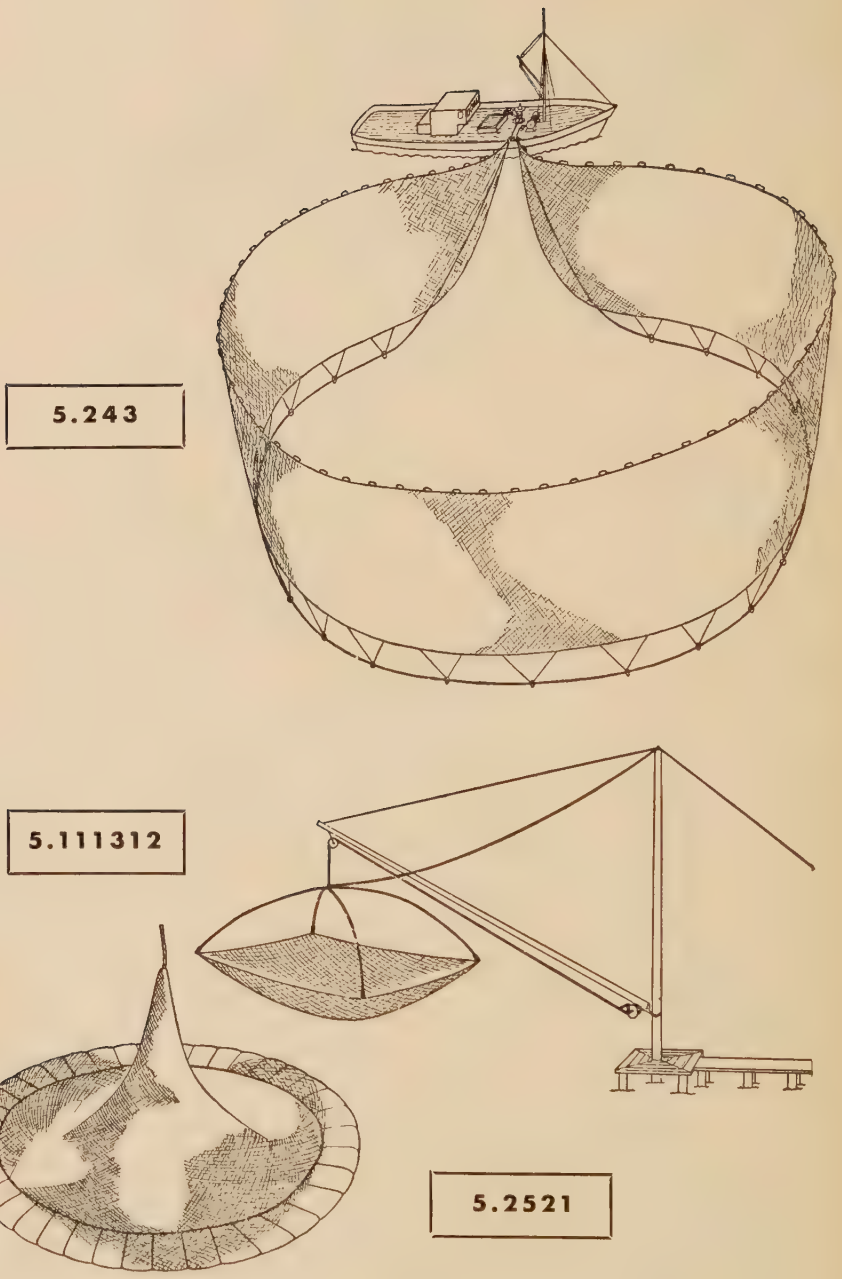

FIGURE 1 (concl.) - Types of fishing gear

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